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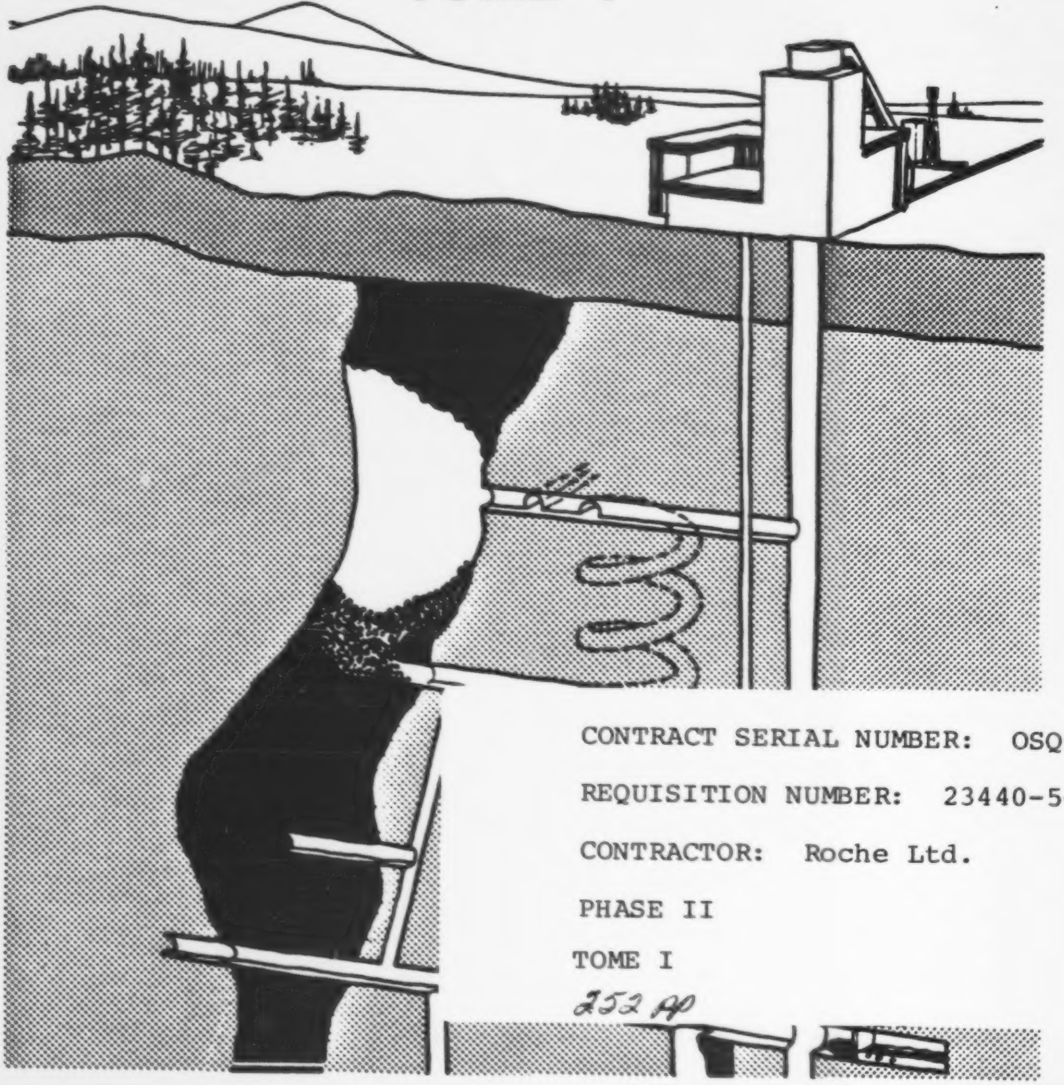
SURFACE PILLARS - PHASE II

TOME I



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PHASE II

TOME I

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ROCHE MINES
Ltée Groupe-conseil

FINAL REPORT

AUG 15 1988

MICROMEDIA

ROCHE
Ltee Groupe-conseil

2535, boul. Laurier,
Sainte-Foy,
Québec,
Canada
G1V 4M3
(418) 871 9600
Telex :QBC 051-31593

St.Foy, October 9, 1985

Mr. Marc Betournay, Eng.
Scientific Delegate
CANMET
555 Booth Street
Ottawa, Ontario
K1A 1G1

Re: Final Report
Surface Pillar Case Studies - Phase II

Dear Sir,

The ROCHE CONSULTING GROUP is proud to submit the final version of the report (15 copies in English and 15 copies in French) ensuing from the case studies. This report is composed of a synthesis and eighteen (18) cases of selected mines.

The data pertinent to surface pillars collected from the eighteen mines visited completes Phase I (Design and Stability of Surface Pillars) submitted in February 1984.

We undertook to gather all available information on the sizing of surface pillars without passing judgement on the quality or design of the pillars studied in any of the mines.

The study of surface pillars (Phases I and II) clearly demonstrates the necessity of establishing a sizing

... /2

procedure that is flexible enough to take into account a variety of ground conditions, yet concise enough to give a sense of security to those responsible for design.

In our opinion, each mine should open a file on its surface pillar(s); this file should evolve recording studies conducted and actions taken in chronological order. This would contribute greatly to the conservation and development of expertise in the sizing of surface pillars.

We sincerely hope that this report meets your expectations and remain at your disposition should you require any further information.

Respectfully yours,

Marcel Allard

Marcel Allard, P. Eng.
Director
Mines Division

MA : DJ

Energy, Mines and Resources Canada
Research and Technology

Énergie, Mines et Ressources Canada
Recherche et Technologie

FINAL REPORT

SURFACE PILLAR CASE STUDIES - PHASE II

(CE RAPPORT EST DISPONIBLE EN FRANÇAIS)

OCTOBER 1985	YOUR FILE : # 03SQ.23440-5-9014 OUR FILE : # 4649-0000-0000

ROCHE
Ltée Groupe-conseil

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0.0 INTRODUCTION

In 1983, a preliminary study was conducted on the stability and sizing of surface pillars. The objective of this study was to verify the possibility of formulating a general approach to surface pillar design, using bibliographic research and six (6) case histories. At the same time, this study was used to summarize the nomenclature of different kinds of pillars including surface pillars.

Based on this report, the following consensus was reached. Each situation is unique. Moreover, the sometimes extreme geological context of a property necessitates an individual, often original approach to the design of the surface pillar or pillars. In brief, no formal method is known to exist.

CANMET thus found it desirable to increase the number of case histories in order to obtain a more representative sampling of Canadian metal mines. All of these case histories could then be used to support an eventual design manual which would provide indispensable guidelines to the design of surface pillars.

. Mandate and Objectives of the Study

The ROCHE CONSULTING GROUP was given a mandate to produce eighteen (18) cases of Canadian mines that either had or had had surface pillars. These mines had to represent situations as geologically varied as possible and possess pillars of different composition and configuration.

Each case history was to examine, if possible, the following aspects:

- Overall evaluation of the mine
- Positions and responsibilities of the personnel involved with pillar design
- Geology of the surface pillar area
- Design method used
- Operating methods of the mine
- Visual evaluation of the surface pillars

The ultimate objective of the study is to single out from the information compiled during the visits those elements most likely to assist operators in the design of surface pillars.

. Contents of the Study

The present document is composed of eighteen (18) sections representing each of the mines studied as well as a synthesis.

In each of the sections, as many facts as possible have been reported without, however, passing judgement on the quality of the mining operations. As for the synthesis it is intended more as an overall description of the findings of the case studies. Tables have been provided to allow readers to select those cases corresponding to their needs. Thus, the person particularly interested in a situation where there is a substantial layer of clay at the surface will be able to identify the pertinent section or sections from the table.

Furthermore, all the case histories have been compiled using the same format in order to facilitate presentation. It is therefore normal that certain chapters are more developed in some mines than in others. There are some situations where subjects examined in most of the mines will not be touched upon at all in certain case histories. Thus, certain subjects are not developed in certain contexts either because they were not pertinent to the property or because management does not see the utility of pursuing the issue or does not carry out certain work for any number of reasons.

Finally, the table of contents of each of the case histories as reproduced in Table 0.1 is identical from one case to the next, except, of course for the numbering which ranges from 1 to 18.

(EXAMPLE) TABLE OF CONTENTS

PAGE

(From 1 to 18) .0 SUMMARY OF THE VISIT..........................

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- Characteristics of the Deposit

.2 MINE ENVIRONMENT..............................

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- Stratigraphy and Characteristics

.4 ROCK MASS ....
- Nature of the Rock
- Structural Geology
- Characteristics

.5 HYDROGEOLOGICAL CONDITIONS ....
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.6 MINING OPERATIONS ....
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TABLE 0.1

0.1 METHODOLOGY

. Choice of Mines

The choice of the mines was established jointly by CANMET and the ROCHE CONSULTING GROUP LTD, and was made in accordance with the objectives previously described. Among other things, the choice favored established mines having operated for a few years and thus more likely to have compiled basic data.

. Data Collection

The collection of information at the designated sites was carried out by a team of two specialists: a Mining Engineer who covered those aspects related to underground operations and a Geological Engineer with a geotechnical background who evaluated the geological context and soils.

A standard questionnaire was used to compile the required information. The questionnaire was completed during the visit to the mine and covered the following aspects:

- General information (type of deposit, geology, etc.)
- Mine environment
- Overburden
- Rock mass
- Hydrogeological conditions
- Mining operations
- Reinforcement methods
- Monitoring programs
- Pillar design and personnel involved
- Visual evaluation of the pillars

On average, the duration of a mine visit was two (2) days.

Depending on the Company, personnel from the Geology, Engineering or Rock Mechanics departments were interviewed to obtain their opinions on these topics. Afterwards, the visit was completed with a tour of the underground drifts.

. Data Processing

The quantity of general data gathered at the mines was sometimes impressive. It was principally composed of general plans, plans of surface pillars, descriptive reports of the property and resumes of specific reports.

It was therefore necessary to condense the information without oversimplifying. Along the same lines, the illustrations in this text are sometimes idealistic rather than realistic. In certain instances, our team had to produce new plans in order to better represent the context of the surface pillars. They are, however, representative of the elements which should be considered in the evaluation of surface pillars.

. Definition of terms

It is appropriate at this stage, to define some of the terms occurring frequently in this study, the first of which is "surface pillar".

SURFACE PILLAR	: Rock mass of variable geometry, containing ore or not, situated over an upper excavation in the mine; used to insure permanent or temporary stability of the surface elements.
OVERBURDEN	: All of the soil located above the rock mass. Of varied composition and thickness, this soil is distinguished from the rock by its very low cohesion. It has no capacity for self-support given the scale of an average stope; it must therefore be supported by surface pillars so as not to invade the stopes of the mine.
ROCK MASS	: The term includes all types of rock formations whatever their competence.
BODY OF WATER	: Refers to a lake, river, basin, etc. as opposed to the water table or to water contained in the interstices of the soil or to underground water veins.
UPPER STOPE	: Exploitation chamber situated at the upper level immediately below the surface pillar.

0.2 GENERAL DATA ON THE MINES VISITED

In a study on surface pillars, certain parameters will necessarily be considered in an initial analysis. These highlight the surface environment and the physical characteristics of the deposits. It is also important to indicate the mining method used, whether or not fill is used, and the average pumping rate.

The eighteen (18) cases studied are therefore described in Table 0.2 in relation to the following points:

- Presence of water bodies on the surface
- Thickness of the overburden
- Form of the deposit
- Dip
- Principal mining method
- Use of fill
- Pumping rate

The values in the table should be considered as reasonable averages for a given property; it may thus occur that, in a single stope, these values vary slightly.

. Soil Characteristics

The typical profile of the overburden in most of the mines is one of deglaciation. Very often, there is till and layers of clay, silt and sand over the ore zones. The thickness of the soil varies greatly from one site to another. Certain mines have no surface overburden while others are located under more than 100 ft (30 m) of clay, sand, etc.

SURFACE PILLAR CASE STUDY - PHASE II
GENERAL DESCRIPTION OF THE MINES

ITEMS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
. BODY OF WATER (m)	-	-	3	(1)	-	-	-	7.6	-	(1)	(1)	-	20	-	-	-	-	-
. OVERBURDEN (m)	(2)	(2)	27	36	4	15	5	20	17	16	20	15	3	5	30	9	1.5	(2)
. FORM OF THE DEPOSIT - tabular	*				*												*	
- single vein			*	*				*	*	*	*		*		*			*
- multiple veins		*				*	*							*				
- mass												*				*		
DIP(degrees)	70°	70°	65°	45°	72°	80°	80°	90°	45°	70°	80°	85°	45°	85°	75°	75°	33°	70°
. MAIN MINING METHOD - stope and pillars																	*	
- shrinkage stoping					*	*	*		*									
- cut-and-fill			*					*					*					
- blasthole stoping	*	*		*						*		*		*	N/D	*		*
. USE OF FILL	NO	YES	YES	NO	NO	NO	NO	YES	YES	NO	YES	YES	YES	YES	N/D	YES	NO	YES
. PUMPING RATE L/s	13	2.2	13	4.6	11	9.5	17	61	11	32	N/D	17	28	14	56	19	16	25
NOTE (1): DEWATERED BODY OF WATER (2): STRIPPED OVERBURDEN																		

TABLE 0.2

. Geological Context

The majority of the mines visited are located in the volcanic rock and/or Precambrian sediment of the Churchill and Superior Provinces. The rock formations containing the ore are characterized by green schist and/or amphibolite metamorphic facies. Two (2) mines, however, are situated in more recent rock, that is, of Ordovician and Silurian origin.

. Use of the Case Histories

Access to the information contained in the eighteen (18) case histories is obtained by consulting Table 0.3. This is a complement of Table 0.2, specifying the major elements found in each of the case histories: the aspects which have been particularly well analysed or described by one Company or another or the special conditions prevailing at such and such a site, etc.

This does not, however, exclude the possibility that other Companies have done research in these areas.

SURFACE PILLAR CASE STUDY - PHASE II
PRINCIPAL ELEMENTS OF THE MINES

ITEMS.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
CONTEXT																		
. Substantial clay deposits			*	*				*	*		*	*		*				
. Pronounced alterations	*			*	*			*						*			*	
. Walls of low competence	*	*	*		*			*					*	*	*	*		
. Walls of high competence						*	*			*								
. Dry mine		*		*														
WORK																		
. Characteristics of the soil				*				*			*	*						*
. Characteristics of the rock		*																*
. Specific sizing criteria		*							*		*		*	*		*		*
. Stress measurements		*	*							*						*		*
. Rock profile						*		*			*							
. Grout injection								*				*						
. Displacement measurements		*								*		*		*		*		*
. Concrete reinforcement											*							

Table 0.3

0.3 PERSONNEL INVOLVED IN DESIGN

The design of ground operations in general and, when applicable, of surface pillars is the responsability of the Engineering Department. However, when extreme conditions are encountered, Companies often consult independant engineering firms. In latter case, the consultants are required either to propose solutions or to confirm a study already conducted by the Company.

When design is effectuated by the Mine's Engineering Department, i.e., when conditions are relatively normal, the Planning Engineer produces the preliminary study. This study is normally carried out in close collaboration with Rock Mechanics where it exists, and Geology Departments. The initial design is then approved by the Chief Engineer and other higher decision levels in the company.

0.4 APPROACH AND DESIGN CRITERIA

. General

The procedure following sizing of the surface pillars depends on the economic priorities fixed by the Companies and also on the level of technology at the time of the pillar design. The 1960's and 1970's marked a turning point in the approach to design with the development of rock mechanics.

Before this time, surface pillar design was almost entirely based on the accumulated experience of a few people who had worked in various mines. This experience was not, however, set down on paper and was only rarely aired in public. At this time, the people in charge of surface pillar design used a method based on trial and error, and even without the latest developments in rock mechanics. They could usually recognize the dangerous conditions related to a rock mass presenting major discontinuities, oxidation zones, etc.

In practice, this procedure resulted, in the case of relatively sound rock masses, in surface pillars of thicknesses corresponding to about two to four times the width of their underlying stopes. In the other cases where the conditions of the rock mass were more precarious (where an oxidation zone caused by water infiltration from a lake was situated just above the pillar) the ratio of the thickness of the pillar to the width of the stope could vary between 5 and 8.

Most of the mines visited had surface pillars which had been designed and maintained during this period (prior to the 1960-70's). The main consequence of this, as pointed out herein, is the lack of pertinent data related to design: rock mechanics was scarcely developed and the persons who were responsible for sizing of the pillars at that time are generally no longer on staff. Also, as witnessed during our visits, these people did not, as a rule, produce and keep written files on the sizing procedure.

It should be pointed out that during the 1960-70's, rock mechanics went through rapid development and influenced pillar sizing in general. The first rock mass behaviour models were simulated by numeric calculations developed toward the end of the 1960's. Since that time, numerical calculations have been developing increasingly and take into account a growing number of parameters characterizing ground conditions. Data gathered during field and laboratory programs are filtered and analysed; this has been noticed in a smaller number of mines and particularly in those that are more recent.

The importance each mine attributed to such programs varied according to the potentially dangerous conditions which could affect the stability of their pillars during mining operations.

In order to recover the surface pillars, or parts of them, certain mines undertook restricted rock mechanics programs, except for mines #3 and #18, where a more elaborate program was conducted to evaluate the effect of an open pit mine on underground operations.

. Design Criteria

Most of the mines followed no real procedure in the design of surface pillars, i.e. they did not undertake steps such as those outlined in Table 0.4.

Of the eighteen (18) cases studied, usage of different methods for the design of surface pillars was as follows:

Method	%
Previous experience	41
Cutoff grade	18
Simple mathematical calculation	29
Geometry	12

One of the approaches most often cited is "experience". This term is very general; although it could be interpreted as a weak excuse for neglecting another approach, this is not believed to be the case.

It should be realized that these surface pillars were left as a result of a decision or judgement that is now impossible to specify but that is generally valid. In fact, only two (2) of the eighteen mines were taken by surprise by pillar cave-ins; there are doubtlessly other such cases not included in this study.

A mathematical calculation was used in cases #1, #2, #3 #9 and #18. In the first two of these cases, the beam theory prevailed. In the third and fourth cases, numeric models were used and in the last, the stress distribution (on a secondary face) was used combined with pillar strength obtained by an empiric relationship.

1. OBSERVATION
   - Body of water
   - Overburden
   - Geometry of the openings
   - Fracturing and general stability

2. MEASUREMENTS
   - Properties of the soil and rock
   - Stress and displacement
   - Flow of water

3. QUANTATIVE AND QUALITATIVE ANALYSIS OF DATA

4. DESIGN
   - Experiments
   - Simple mathematical calculations
   - Numerical models

5. VERIFICATION
   - Inspection
   - Instruments
   - Simulation

TABLE 0.4

In 12% of the cases, design was based on the geometric relationship between the thickness of the surface pillar and the width of the underlying stopes, the latter being measured between the walls of the deposit. One should, however, be aware that this ratio varies considerably since the mines tend to establish an average upper level above which no more exploitation is carried out.

Finally, in 18% of the cases, the content did not justify recuperation of the upper part of the deposit. It should be noted that the percentages mentioned above were calculated on the basis of 17 mines; mine #15 has no proper surface pillar since the working of the stopes has not been started.

0.5 PILLAR GEOMETRY

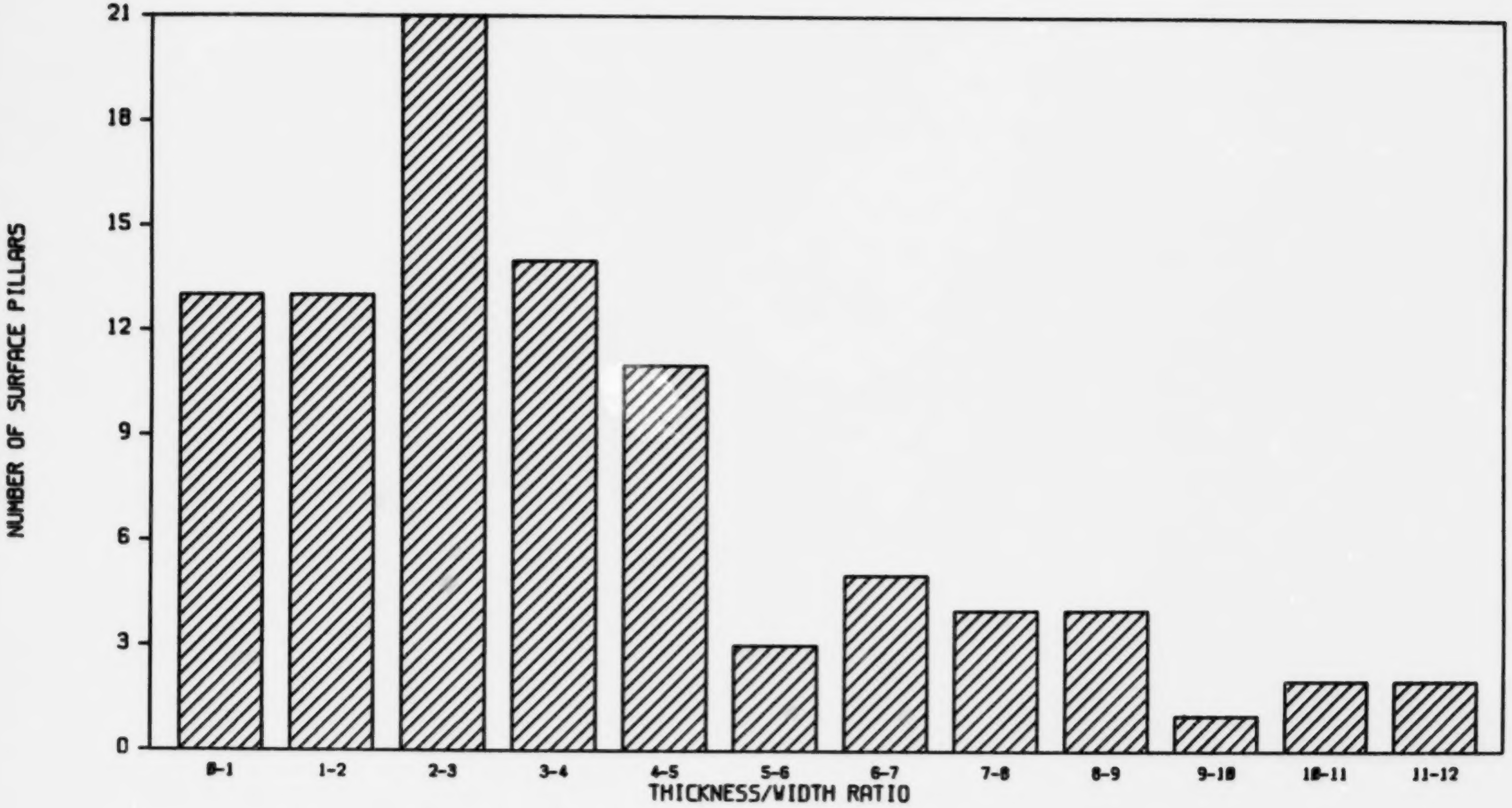
The geometry of surface pillars may be perceived in two ways. The surface pillar may be imagined as a monolithic block covering the entire length of the deposit. In this case, this block is generally supported by transverse pillars which link the two (2) walls and is undercut along varying lengths.

The surface pillar may also be perceived as being the roof of each of the stopes. Since the stopes have a well defined width and length, the pillar will have the same dimensions, plus a thickness corresponding to that of the rock situated immediately above. A property could therefore have as many surface pillars as it had stopes at the first level of the mine. This is the approach we have used.

Since all but two (2) of the deposits visited were in tabular or vein form, thus longer than wide, the surface pillars also had this common characteristic.

Figure 0.1 represents a histogram of the thickness/width ratio of the surface pillars. It is evident that the range of values is wide and skewed to the right. In all, 103 surface pillars were encountered during the visits to the mines; however, 9 cases were eliminated because their thickness/width ratio was greater than 12 and their ore-content was not economic. The 94 cases retained had an average of 3.7 and a standard deviation of 2.7. This average corresponds to the values given by those mine manager who claimed to have used factors of 2 to 3 in the design of surface pillars.

"THICKNESS/WIDTH RATIO" DISTRIBUTION



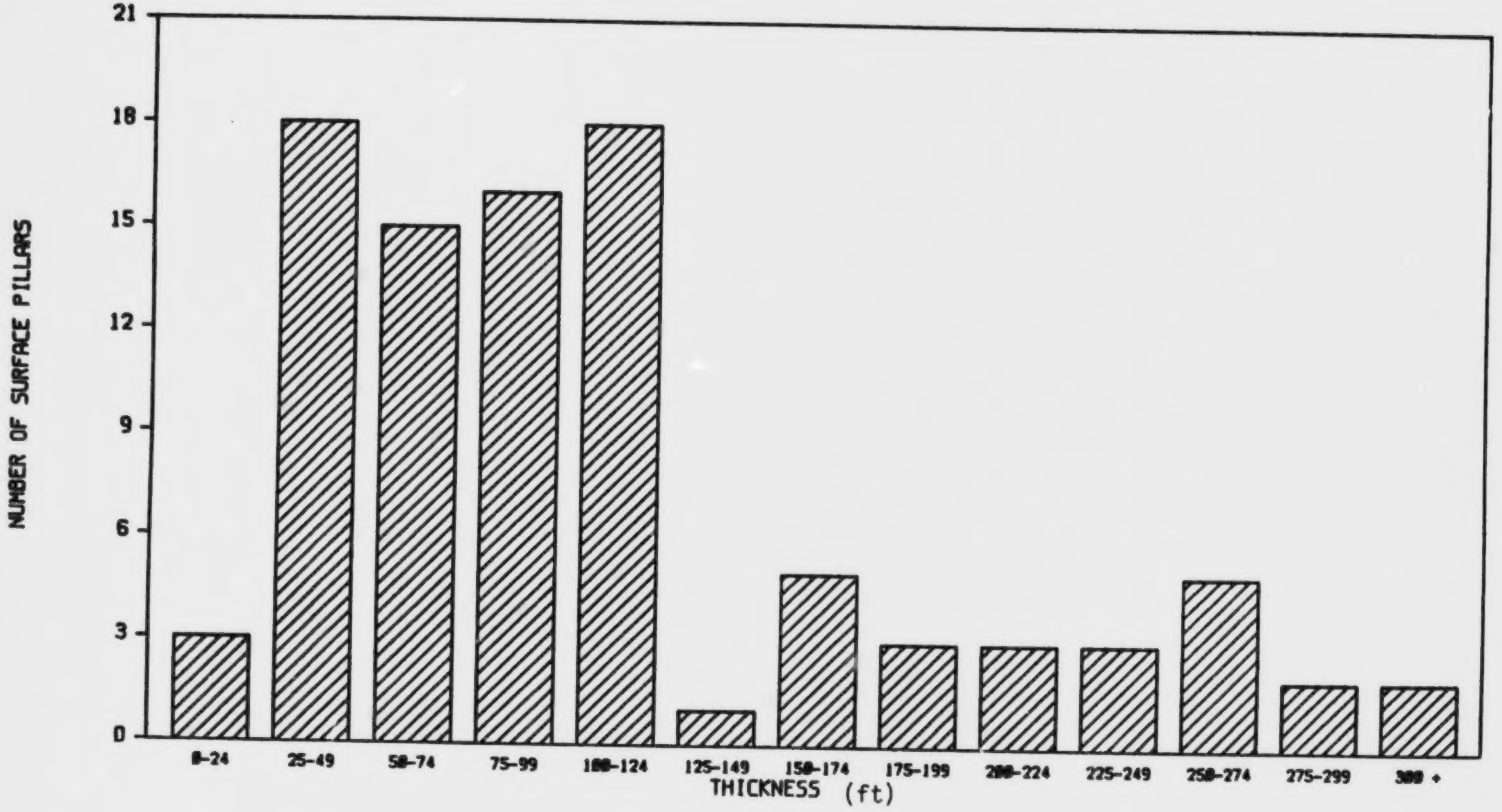
POPULATION: 94 SURFACE PILLARS

Figure 0.1

It is noteworthy that values between 1 and 2 are encountered in mines which are not covered either by overburden or by bodies of water. Higher levels are encountered in mines situated in highly fractured or altered rock masses or where water infiltration is relatively high.

Figure 0.2 shows the distribution of the thickness of the surface pillars. The two main population groups correspond to the 45 and 100 ft exploitation levels (14 and 30 m). The surface pillars studied average 108 ft (33 m) with a standard deviation of 80 ft (24m). As for the width of the surface pillars of the underlying stopes, the average is 10 ft (15 m) with a standard deviation of 62 ft (19 m); this latter value reflects the dispersion of the widths towards the higher values. The correlation coefficient between the width and thickness of the surface pillars is only 0.44, which means that we cannot establish a direct relationship, on the whole, between the width of the upper stopes and the thickness of their corresponding surface pillar.

THICKNESS DISTRIBUTION



POPULATION: 94 SURFACE PILLARS

Figure 0.2

0.6 DISCUSSION AND CONCLUSION

The following series of comments represents those points which were either discussed with personnel or noticed at the time of the visits.

- Of the eighteen (18) mines visited, only two cases of caving of the surface pillars were observed. All the other pillars appeared to be stable.

- We noticed that the amount of effort put into pillar design is proportionnal to the conditions and level of instability:
  - High degree of fracturing in the rock mass
  - Dense oxidation zone
  - Body of water at the surface
  - Presence of major discontinuities
  - Considerable thickness of overburden
  - Presence of infrastructures at the surface
  - Presence of open pit mine(s)
  - Hydrogeological conditions

- Only seven (7) mines had a file on their surface pillars.

- No mine had drawn up a detailed plan of its surface pillars.

- Investigative work on the upper part of the rock mass is often undertaken by companies hoping to reduce the thickness of surface pillars previously left in place.

- In cases where the deposit touches the surface or where a thin layer of overburden (<20 ft:<6 m) covers the ore zone, the approach to sizing is generally simpler. Exploitation of the upper stopes is simply stopped when it becomes convenient to leave temporary pillars a thickness of double or triple the width of the stopes, and recovery is later resumed from the surface.

- The general evaluation of the surface pillars, contributed verbally by each of the companies, is mainly based on subjective criteria. None of the mines visited had sufficient information to state that this or that surface pillar was very safe, or close to caving. Quantification of stability in terms of safety factors (approximated) is still not possible because of the overly high degree of variation in the physical properties of the rock mass. These variations include discontinuities in the rock, water infiltration, etc., and they complicate any mathematical approach (stress calculations) used to evaluate pillar stability and to justify, if necessary, the implementation of monotoring programs.

- Therefore, monitoring programs are generally implemented when potentially high instability conditions are actually encountered in the field or afterwards, when a stope roof has caved-in or in the case of obvious surface subsidence.

- As could be predicted from the heterogeneity of the rock formations, the results of geomechanical testing vary highly for the same type of test. For example, the compressive strengths can vary between ± 10 and ± 50%.

- In general, the results of geomechanical testing given in this study come from reports prepared by external consultants or by masters or doctoral level students hired by the mines concerned.

- Our visual evaluation of the various surface pillars indicated that the stability conditions and the quality of the rock mass could vary considerably in the same stope. Any evaluation of the stability of a given pillar should be based not only on a general study but also on a set of specific programs ensuing from surface pillar zoning including walls and support pillars.

- In our opinion, the truly useful surface pillar data do not lead, on the whole, to the emergence of a sizing procedure based on quantitative analysis of the acting stresses in the upper part of the mine. We believe, however, that the mining organizations have on hand the appropriate design tools to conduct a semi-quantitative evaluation which would include both the practitioners' experience and the recent developments in rock mechanics.

Serge Nantel

Serge Nantel, P. Eng.
Project Director

Denis Lessard

Denis Lessard, P. Eng. M.Sc.
Project Engineer

MINE #1

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1.0 SUMMARY OF THE VISIT

The deposit consists of massive sulfides, mineralized into copper and zinc. The upper part of the deposit is in tabular form, 1 500 ft long (460 m) and 100 ft 30 m) wide with a dip of 70° NW. The walls are mainly composed of gneiss.

The overburden, between 20 and 30 ft (6 and 9 m) thick , has been removed from above the surface pillars. This layer of overburden consists of sand and gravel.

A lake, located in the orebody area, was dewatered. In the rock mass, the output of pumped water is low, with values ranging from 170 to 180 IGPM (13 L/s) for the overall mine. These values include the water coming from fill and equipement.

The surface pillars have an average thickness of 30 ft and cover 8 stopes, two of which have been completely filled. No special monitoring program has been developed for the upper stopes. These upper stopes have been drilled from the surface using a 10 x 10 ft (3 x 3 m) drill pattern and using blastholes (200 ft: 60 m) with a diameter of 6½ in (16.5 cm). The rock of the walls is competent in most of the stopes. A rock mechanics program was established in 1969-70 allowing for stability analysis by extrapolation of the surface pillars, based on the beam theory. Wall pillars have been left for primary support. Eventually, the surface pillars will be mined.

1.1 GENERAL INFORMATION

. Regional Geology

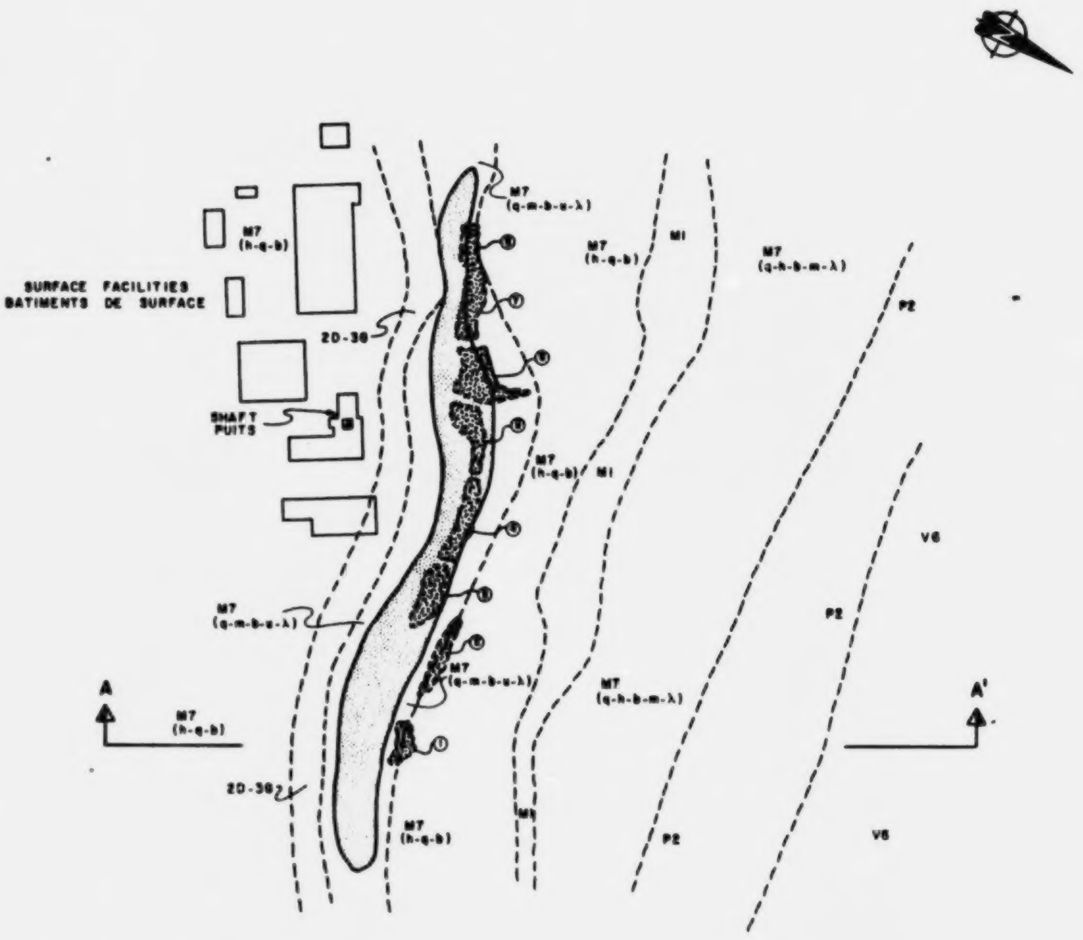
The mining property is located in the Churchill Province, or more precisely, in mafic to intermediate metavolcanic rocks. A major fault crosses the region striking NE-SW. The metavolcanic rock is bordered to the north by granite and granitoid gneiss and to the south by metasediments. These Precambrian formations create a belt of folded metavolcanic and metasedimentary rock. The region is marked by the amphibolite facies.

. Local Geology

The orebody is situated in an altered zone composed of biotite, sericite and amphibolite gneiss. The south side of the deposit is made up of dioritic and gabbroic rock located at the interface with the alteration zone and further away quartz hornblende gneiss with some biotite. The north side is made up of a series of gneiss similar to that described in the south part: schistic sediment containing some sulfide and again, gneiss. (See figures 1.1 and 1.2).

. Characteristics of the Deposit

The orebody is made up of massive and disseminated sulfides of the volcanic type. The ore is composed of copper, zinc and very small quantities of gold and silver.


SURFACE FACILITIES
BATIMENTS DE SURFACE
SHAFT
PUITS
M7
(h-q-b)
M7
(q-m-b-u-λ)
M7
(h-q-b)
MI
M7
(q-h-b-m-λ)
P2
V6
2D-30
M7
(q-m-b-u-λ)
A
A'

LEGEND - LEGENDE

SUFFIX - SUFFIXES

b: biotite
h: hornblende
m: muscovite
q: quartz
u: amphibole
λ: sericite
séricite

SYMBOLS - SYMBOLES

▨ Sulphide zone (copper-zinc)
Zone de sulphure (cuivre-zinc)

MI Slatey sediments
Sédiments schisteux

M7 Gneiss

P2 Arkose

V6 Andesite
Andésite

2D-30 Diorite - Gabbro

① ▨ Upper stopes
Chantiers supérieurs

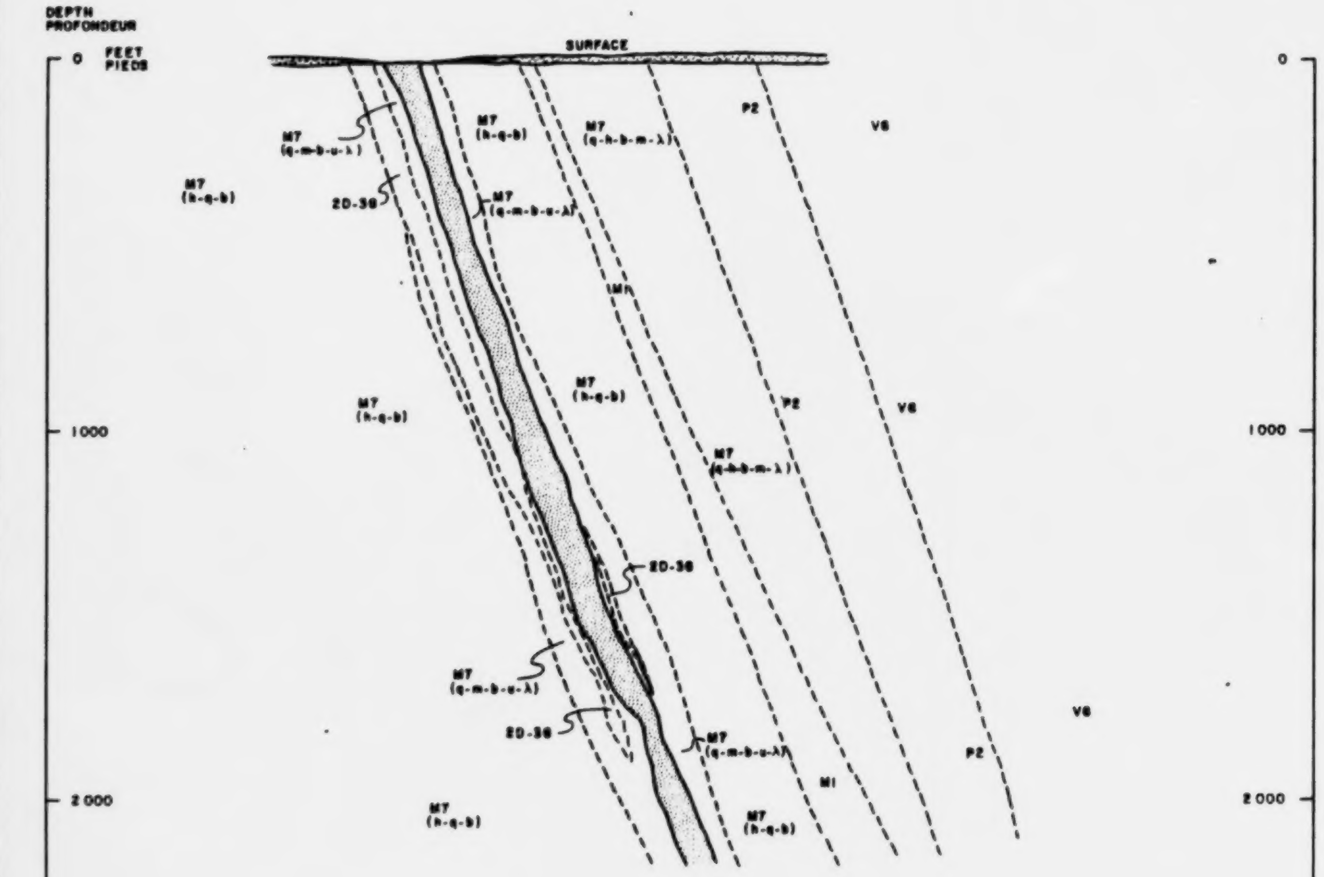
0 100 200
FEET - PIEDS

ROCHE

MINE #1 MINE

SURFACE PLAN
PLAN DE SURFACE

Date 06/85
Figure 1.1


DEPTH
PROFONDEUR
FEET
PIEDS
0
1000
2 000
SURFACE
M7
(q-m-b-u-λ)
M7
(h-q-b)
2D-36
M7
(h-q-b)
M7
(q-h-b-m-λ)
M7
(q-m-b-u-λ)
P2
V6
MI
M7
(h-q-b)
M7
(h-q-b)
P2
V6
M7
(q-h-b-m-λ)
2D-36
M7
(q-m-b-u-λ)
2D-36
M7
(q-m-b-u-λ)
MI
P2
V6
M7
(h-q-b)
M7
(h-q-b)
0
1000
2 000

LEGEND - LEGENDE

SUFFIX - SUFFIXES

b:	biotite	q:	quartz
h:	hornblende	u:	amphibole
m:	muscovite	λ:	sericite séricite

SYMBOLS - SYMBOLES

▨	Sulphide zone (copper - zinc) Zone de sulphure (cuivre - zinc)
MI	Slatey sediments Sédiments schisteux
M7	Gneiss
P2	Arkose
V6	Andesite Andésite
2D-36	Diorite - Gabbro

0 100 200
FEET - PIEDS

SECTION
COUPE A-A'

ROCHE
associés ltée
Groupe conseil

2535, boul Laurier
Sainte-Foy, Québec
G1V 4M3 Canada
(418) 871 [illegible]
Télex CB [illegible]

MINE #1 MINE

GEOLOGICAL SECTION
COUPE GEOLOGIQUE

Date	Figure
06/85	1.2

The massive sulfides are in tabular form divided into two distinct lenses of greater depth. The dimensions of the deposit are:

length	width	depth
1500 ft	100 ft	2900 ft
(460 m)	(30 m)	(880 m)

The deposit has a strike of N72°E and a dip of 70°NW.

Production is continuous and close to 3 000 tons are extracted daily.

1.2 MINE ENVIRONMENT

No infrastructures have been established directly over the surface pillars. The rock mass is covered with glacial soil. Since the beginning of mining operations, no surface settlement has been observed.

The mine offices and main shaft are situated close to the surface pillars, approximately 200 ft (60 m) away. (See Figure 1.1).

No other mine or major excavation is situated in the vicinity of the mine visited.

1.3 OVERBURDEN

. Studies

No geotechnical study has been conducted on the soils covering the surface pillars. These soils, between 20 and 30 ft (6 to 9 m) thick, were removed to allow for surface drilling of the mine.

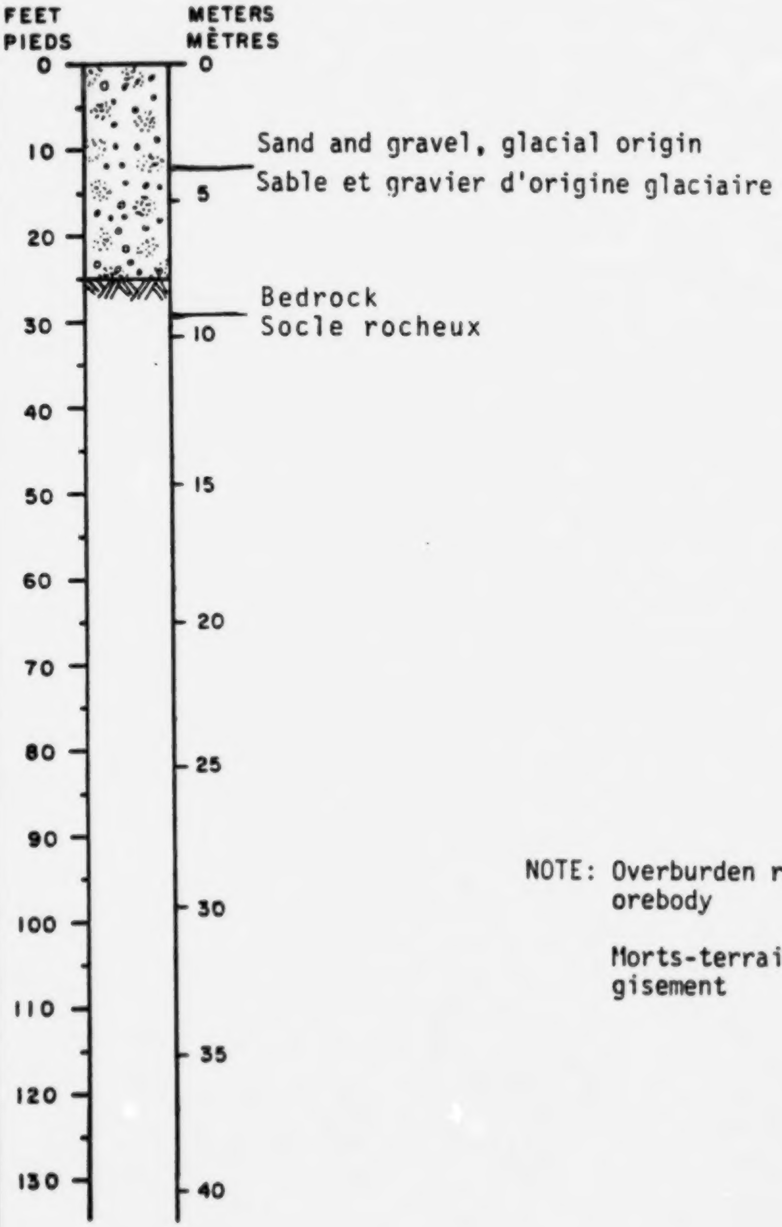
The portion of the overburden covering the surface pillars was dewatered and removed in 1979. Presently, the pillars are covered in places by cuttings and sediment deposited by surface water. According to mine management, there is presently a maximum of 4 to 5 ft (1 to 1.5 m) of loose material over the surface pillars.

Regional soil studies have already been undertaken in order to find materials to best fill the stopes.

. Stratigraphy and Characteristics

The soils covering the surface pillars were mainly composed of sand and gravel of glacial origin. (See Figure 1.3).

SOIL STRATIGRAPHY
STRATIGRAPHIE DU SOL


FEET
PIEDS
METERS
MÈTRES
0
10
20
30
40
50
60
70
80
90
100
110
120
130
0
5
10
15
20
25
30
35
40
Sand and gravel, glacial origin
Sable et gravier d'origine glaciaire
Bedrock
Socle rocheux

NOTE: Overburden removed on top of the orebody

Morts-terrains enlevés au-dessus du gisement

ROCHE associés ltée Groupe-conseil	2535, boul Laurier, Sainte-Foy, Québec G1V 4M3 Canada (418) 871 9600 Télex: QBC 051 31593	MINE # 1 MINE	Date 07-1985	Figure 1.3

1.4 ROCK MASS

. Nature of the Rock

The rocks containing the orebody are as follows:

Footwall : gneiss (quartz, mica, sericite, amphibole) gabbro and diorite dykes.

Deposit : massive and disseminated sulfides.

Hanging wall : gneiss (quartz, mica, sericite, amphibole) and schistic sediment

An alteration zone varying from 40 to 100 ft thick (12 -30 m) surrounds the orebody. This zone consists of quartz, sericite, mica (biotite and muscovite) and amphibolites.

. Structural Geology

No major geological structure has been located or mapped in the orebody: fold planes and major faults are extremely rare.

No particular study has been conducted on the joints. According to mine management, only one upper stope has a highly fractured roof. As a protective measure, an additional layer of rock 10 ft (3 m) thick has been left in the roof of this stope.

The gneissosity remains practically parallel to the strike of the orebody.

. Characteristics

During the years 1969-70, a series of tests carried out on rock samples taken from the upper portion of the mine, i.e. above the 2 000 ft level, produced the results compiled in Table 1.1.

The average density of the rock which forms the walls is about 2.9 and 4.4 for the massive sulfides.

Specific tests have been carried out perpendicular to the gneissosity plane and along angles less than 50° from this plane. The results are presented below according to the provenance of the samples:

Direction of applied force	Walls	Young's Modulus psix 10^6	(GPa)	Poisson's Ratio
Perpendicular to the gneissosity plane	hanging	15.4	(106)	0.21
	foot	8.7	(60)	0.06
Less than 50° off the gneissosity plane	hanging	14.8	(102)	0.23
	foot	11.6	(80)	0.19

Compressive strength, in the majority of the rocks, is significantly reduced if the force is applied at a low angle from the gneissosity.

ROCK CHARACTERISTICS

CARACTÉRISTIQUES DE LA ROCHE

TABLE 1.1

TABLEAU 1.1

LOCATION EMPLACEMENT		WALLS EPONTES			OREBODY GISEMENT		WALLS EPONTES		
ROCK TYPE TYPE DE ROCHE		gneiss(quartz-mica amphibole)	gneiss (quartz-hornblende)	gneiss (quartz-feldspath - hornblende)	massive sulphides sulfures massifs	disseminated sulphides sulfures disséminés	basic siliceous rocks roches basiques silicifiées	basic rocks with fine and medium texture roche basique à texture moyenne et fine	gneiss (quartz-biotite)
DENSITY DENSITÉ		2.9			4.4		2.9		
COMPRESSIVE STRENGTH RÉSISTANCE EN COMPRESSION	psi × 10^3 (MPa)	13.1 (90)	-	24.6 (170)	13.9 (96)		28.7 (198)	24.6 (170)	23.8 (164)
SHEAR STRENGTH RÉSISTANCE AU CISAILLEMENT	psi × 10^3 (MPa)								
TENSILE STRENGTH RÉSISTANCE EN TENSION	psi × 10^3 (MPa)								
POINT LOAD STRENGTH INDICE DE DOUBLE POINCONNEMENT	psi × 10^3 (MPa)								
POISSON'S RATIO RAPPORT DE POISSON		0.10	0.25	0.07	0.16	0.08	0.10	0.07	0.16
YOUNG'S MODULUS MODULE DE YOUNG	psi × 10^6 (G Pa)	8.8 (61)	11.2 (77)	11.2 (77)	16.8 (116)	12.2 (84)	8.3 (57)	11.2 (77)	11.7 (81)
RQD %									
GEOMECHANICAL CLASSIFICATION CLASSIFICATION GÉOMÉCANIQUE									

The results of these geomechanical tests have been helpful in the design of the surface pillars. They were used to characterize the pillars and to evaluate their strength using the beam theory.

No R.Q.D. value has been calculated and no use is made of geomechanical classification.

The contact points between the walls and the orebodies are generally distinct and no major chipping has been observed. Only a few local shearing zones have been encountered.

1.5 HYDROGEOLOGICAL CONDITIONS

. Overburden

Hydrogeological conditions at the surface have been modified. A lake in the immediate vicinity of the ore zone has been dewatered. The soil over the surface pillars was also dewatered and then removed.

. Rock Mass

In the rock mass, permeability seems to be very low: only 170 to 180 (I) GPM (13 L/s) are pumped to the surface from the mine. Part of this water comes from fill (30 IGPM) (2.2 L/s) and from mining equipement. Three major pumping systems have been installed in levels 1200, 2300 and 2900.

During the mining of level 200, several water leaks were plugged; water was flowing through exploration holes that had not been blocked off.

1.6 MINING OPERATIONS

. Mining Methods

The deposit is mined using the blasthole and open stope method and the filled after a period of between four and six months. Figure 1.4 illustrates the dimensions of the stopes and pillars at the different levels of the mine.

. Operating Conditions

The stopes are generally mined in the following manner: sub-levels are dug into the ore and then a series of holes are fan drilled upwards on a vertical plane. The upper levels have been worked to date using large diameter (6½ in: 16.5 cm) holes. The upper part of the stopes, located between 30 and 200 ft deep (9 and 60 m), has been drilled from the surface.

The drilling patterns used are as follows:

Large diameter holes: diameter - 6½ in (16.5 cm)
pattern - 10 x 10 ft (3 x 3 m)
depth - 200 ft (60 m) maximum
maximum spacing - 18 ft (5.5 m)

Conventional holes : diameter - 2 in (5 cm)
pattern - vertical fans spaced at 4 ft (1.2 m) intervals
depth - 100 ft (30 m) maximum
maximum spacing - 8 ft (2.4 m)

LONGITUDINAL SECTION

COUPE LONGITUDINALE

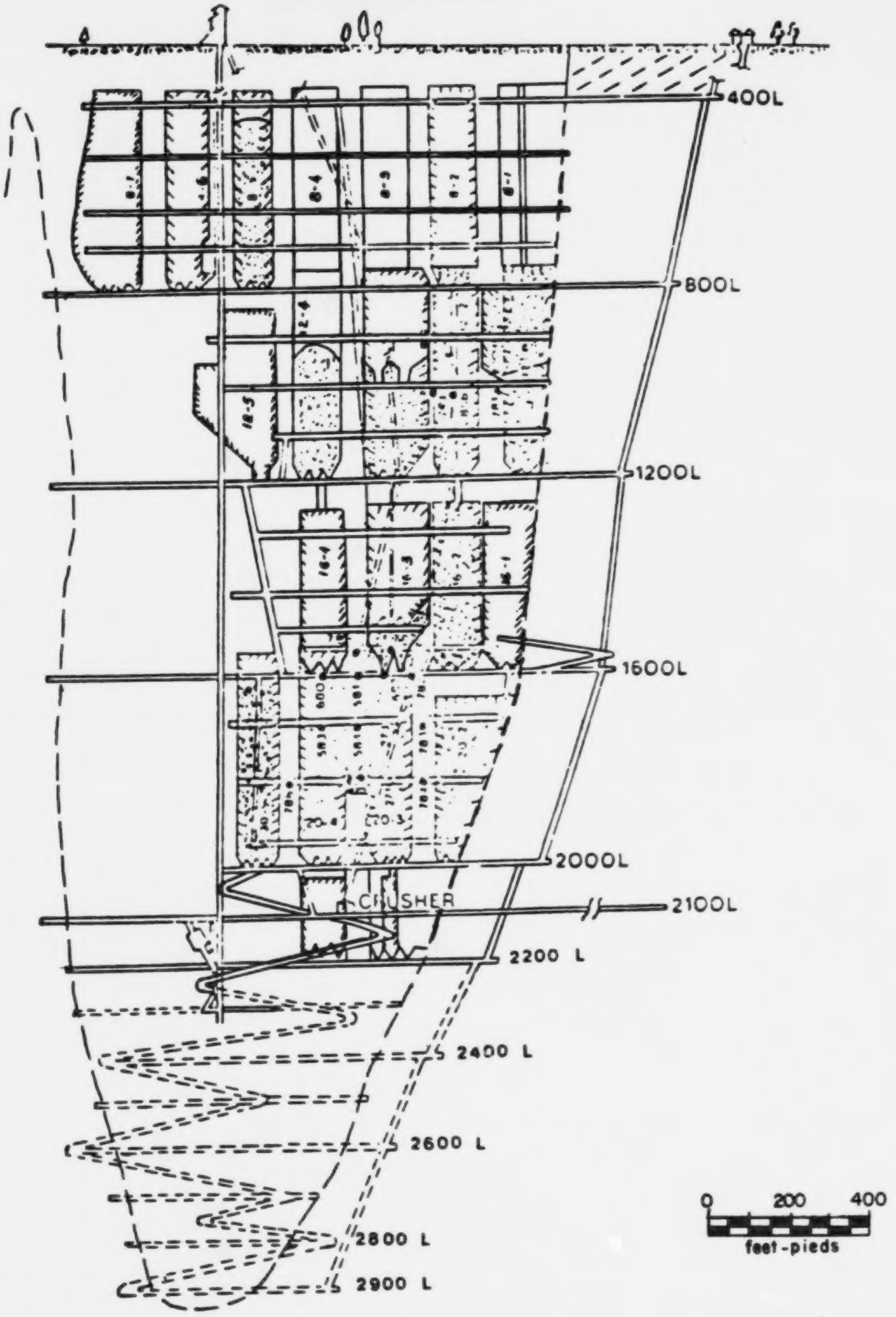

400L
800L
1200L
1600L
2000L
CRUSHER
2100L
2200 L
2400 L
2600 L
2800 L
2900 L
0
200
400
feet-pieds

Figure 1.4

The recovery percentage is about 80% and, after pillar recovery, is close to 100%. Dilution in the upper stopes is from 10% to 12% and about 20% in the deeper stopes.

The mining sequence is as follows:

1 - Mining of numerous stopes between levels 800 and 2000.

2 - Extension of work below level 2000: digging of a ramp.

3 - Mining of numerous stopes located between levels 200 and 800.

4 - Mining of the surface pilars from level 200 to within 30 ft (9 m) of the soil/rock interface.

The interval between the end of mining in an upper stope and filling may vary between a few months and a few years. Of the nine upper stopes, five have been filled, one is partially filled and three are unfilled.

1.7 SUPPORT AND REINFORCEMENT METHODS

. Primary Support

Some wall pillars have been left as primary support for the surface pillars.

. Filling and Reinforcement

At level 200, conventional bolts were installed in some limited areas where the degree of fracturing was high.

During the drilling of the orebody (levels 200 to 400), wooden braces were erected from level 200 to prevent the caving of the roof in one of the stopes under exploitation.

In the active stopes deeper down, conventional bolts are used systematically. Swellex-type bolts have been in use for a year: these bolts represent about 5% of all those newly installed. Steel mesh covers about 10% of the surfaces of the drifts. The use of cables is rare.

Stopes are not all filled with the same material: stopes below level 400 may be filled with sand and gravel, waste rock, mine tailings or with cemented mine tailings (3% cement).

Stopes above level 400 contain exclusively non-cemented mine tailings. Based on percolation tests conducted on tubes filled with tailings, the speed of water flowing through this material is estimated at 5 inches per hour (3.5×10^{-3} cm/s).

The granulometry of the mine tailings returned underground after cycloning:

Mesh #	% retained
48	0.87
65	3.58
100	10.66
150	15.03
200	16.59
325	20.15
>325	33.12

The physical properties of the cemented tailings (3% cement) after 28 days are:

density : 3.42
density of the pulp : 73%
bulk density : 115 lb/ft^3 (18 kN/m^3)
porosity : 42%
maximum saturation : 21%
cohesion : 1 728 lbs/ft^2 (83 kN/m^2)
internal friction angle : 34.50°
uniaxial compressive strength : 461 lbs/ft^2 (3 178 kN/m^2)

1.8 MONITORING PROGRAM(S)

. Stress Measurement

Out of thirty-nine stress measurements taken in the stopes below level 400, only eight had directions approximately parallel and perpendicular to the rock structure. The calculated force fields are generally not associated with the visible structures of the rock. The variations observed in the stress measurements indicate the presence of a complex force field in the vicinity of the deposit.

. Displacement Measurement

Monitoring programs have been carried out on some rib and crown pillars at level 1200 and below. As many as 20 multiple-anchor extensometers have been installed in these levels. Thin pillars left between certain filled stopes showed signs of instability; one of these pillars, separating a partially filled stope from a filled one, had given way under the pressure of the fill. This happened between two shifts and no one was injured. The incident induced management to undertake special studies on the mining and filling operations. The possibility of liquefaction of the fill was studied with respect to water content and to the granulometry of the particles and also in relation to the probability of seismic tremors. The priorities adopted by management accented efficient draining of the fill.

. Other Program(s)

The only special control measure initiated in connection with the surface pillars was the use of geophysical equipment to measure the speed of waves produced during blasting of part of the pillar (30 to 200 ft: 9 to 60 m deep). The speed was limited to 2 inches/second (5 cm/s), in order not to damage the foundations of the collar house situated next to the surface pillars.

A monthly visual inspection is carried out on the upper stopes and drifts. However, during filling of the stopes an inspection is conducted every day and a report produced. The major levels are inspected annually.

During hydraulic filling of the stopes, wooden retention dams are generally equipped with a gauge and a deflection bar indicating changes in the pressure behind the dam.

1.9 SURFACE PILLAR DESIGN

. Personnel Involved

The people and departments involved in the design of the pillars are indicated in Figure 1.5. The Chief Mine Engineer is responsible for design of the surface pillar. The Mine Superintendent approves or modifies the procedure developed by the Chief Mine Engineer and the others involved.

The high grade of copper and zinc in the surface pillars induced management to mine them in successive steps, the last of which will be the recovery of the last slice deep 0-30 ft deep (0-9 m).

Numerous studies have been conducted in this mine covering such aspects as stability, production, mining methods, etc. Most of the studies were concerned with levels 1200 and deeper. Among the studies, there are several reports concerning hydraulic fill, the design of retention dams for fill and the drainage of filled stopes. A 1970 report by an outside consultant gives a summary of the research on rock mechanics carried out in different levels of the mine. Among the results given, the span of the stopes, calculated using the beam theory, would be as follows:

massive sulfides (hanging wall): 240 ft (73m)
quartz, mica and amphibolite gneiss (hanging wall): 140 ft (43 m).

ORGANIZATION CHART - PILLARS DESIGN
ORGANIGRAMME - CONCEPTION DES PILIERS

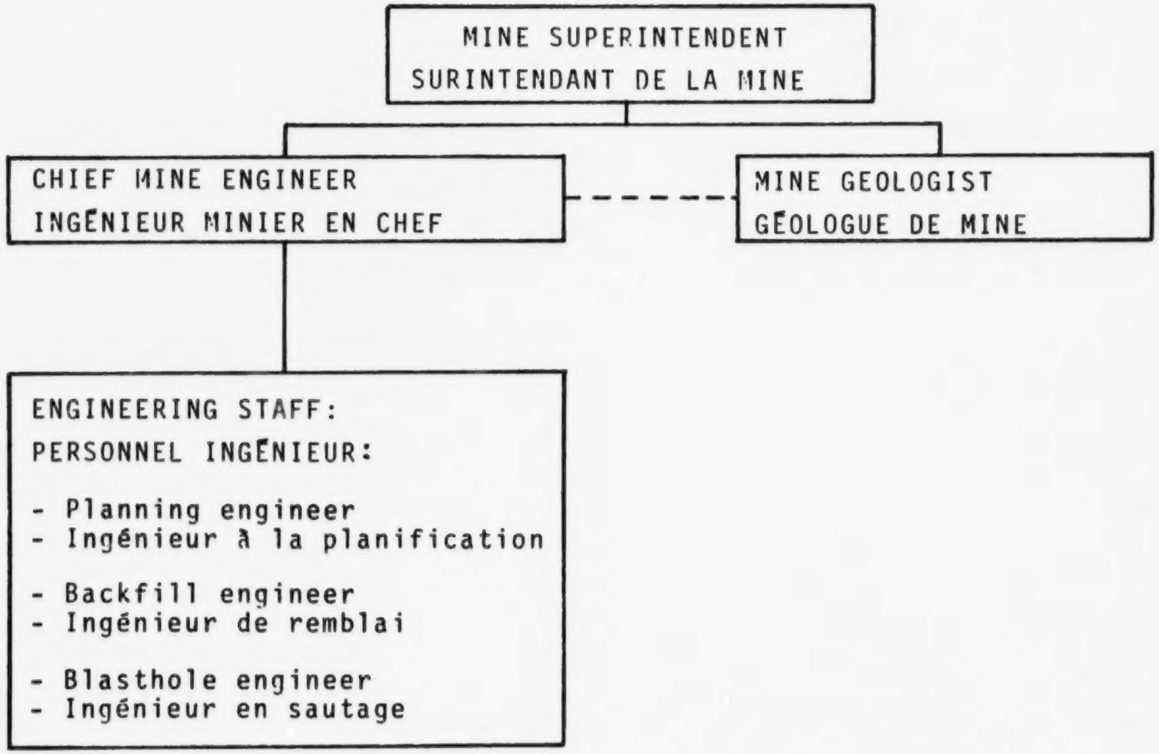

MINE SUPERINTENDENT
SURINTENDANT DE LA MINE
CHIEF MINE ENGINEER
INGÉNIEUR MINIER EN CHEF
MINE GEOLOGIST
GÉOLOGUE DE MINE
ENGINEERING STAFF:
PERSONNEL INGÉNIEUR:
- Planning engineer
- Ingénieur à la planification
- Backfill engineer
- Ingénieur de remblai
- Blasthole engineer
- Ingénieur en sautage

Figure 1.5

Again according to this report, the values should be reduced because of the unfavorable strike of the joints and the weak planes in the rock mass. Stopes with a span of 100 ft (30 m) in the hanging wall could become unstable if left without support for a long period of time. Thin rib pillars should be left in the primary stopes having a span 100 ft (30 m) or more, especially in stopes not filled for several months after mining. According to ground stresses, the rib pillars should have the following nominal dimensions: 40 ft x 70 ft (12 m x 21 m).

Only two studies deal with the surface pillars; one looked into the economic aspect and recommended removal of the overburden to avoid problems and the other, more technical, reviewed stability criteria and procedures for the mining of the pillars. The first study was conducted by mine personnel and the second by an outside consultant; the latter report was not available.

. Chronology

Surface pillars 200 ft (60 m) thick were left intact during the mining of the central part of the orebody. Later, management decided to mine parts of the pillars, reducing them to 50 ft (15 m) thick. The latter was an arbitrary value and was reduced further to 30 ft (9 m) following the recommendations of an outside consultant. It should be pointed out that the primary purpose of the surface pillars was to protect the upper stopes permanently.

The upper stopes were worked from the east to the west, i.e. towards the access shaft.

. Design Factors

Factors for the design of the surface pillars are based on a practical approach developed from previous experience. According to mine management, the dimensions of the pillars are also based on the results of rock mechanics tests (uniaxial compressive strength), Poisson's ratio and Young's modulus. The beam theory was used to estimate pillar strength.

. Pillar Dimensions

Table 1.2 gives the dimensions of the surface pillars. Some of the upper stopes have been partially filled.

DIMENSIONS OF SURFACE CROWN PILLARS

DIMENSIONS DES PILIERS DE SURFACE

TABLE 1.2
TABLEAU 1.2

DIMENSIONS		PILLARS - PILIERS							
		#1	#2	#3	#4	#5	#6	#7	#8
. THICKNESS: EPAISSEUR:									
- WATER BODY PLANS D'EAU	feet-pi. (m)	-	-	-	-	-	-	-	-
- OVERBURDEN MORTS-TERRAINS	feet-pi. (m)	*	*	*	*	*	*	*	*
. SURFACE CROWN PILLAR: PILIER DE SURFACE:									
- THICKNESS EPAISSEUR	feet-pi. (m)	120 (37)	70 (21)	40 (12)	30 (9)	30 (9)	30 (9)	30 (9)	30 (9)
- WIDTH LARGEUR	feet-pi. (m)	30 (9)	25 (8)	45 (14)	40 (12)	45 (14)	90 (27)	40 (27)	40 (27)
- LENGTH LONGUEUR	feet-pi. (m)	100 (30)	190 (58)	150 (46)	190 (58)	160 (49)	120 (37)	150 (46)	70 (21)
- THICKNESS/WIDTH RATIO RAPPORT EPAISSEUR/LARGEUR		4	2.8	0.9	0.8	0.8	0.3	0.8	0.8
. STOPE HEIGHT HAUTEUR DU CHANTIER	feet-pi. (m)	270 (82)	300 (91)	330 (100	340 (104)	340 (104)	340 (104)	340 (104)	340 (104)
. FILL HEIGHT HAUTEUR DU REMBLAI	feet-pi. (m)	230 (70)	240 (73)	270 (82)	340 (104)	340 (104)	280 (85)	340 (104)	280 (85)

* Removed - Enlevé

1.10 VISUAL EVALUATION OF SURFACE PILLAR(S)

The visual inspection of the surface pillars was limited to the entrances of unfilled stopes and to the access drifts.

The rock of the footwall is massive with well developed fracture zones in places. In the western part of the pillar on the wall of a drift running along the footwall, there is a formation of three families of joints with the following characteristics:

	1st Family	2nd Family	3rd Family
host rock :	gneiss (QB)	gneiss (QB)	gneiss (QB)
strike :	240°	300°	200°
dip :	65°N	74°W	32°N
spacing :	irregular	irregular	irregular
spread :	tight	tight	tight
water pressure:	damp wall	damp wall	damp wall

A fault located in a drift (footwall) ending in a semi-filled stope has the following characteristics:

host rock : gneiss (Q-B-A)
strike : 240°
dip : 55°S
spread : 4 to 6 inches
fill : soft schist and clay
water pressure: dripping

Near the entrance to the stope situated the furthest to the west, the ceiling of the access drift is covered with steel mesh held by bolts and metal plates. The bolting of the roof is not done systematically; it is limited to a few rare places where the rock shows pronounced fracturing.

The hanging wall appears to be more massive and more competent than the footwall. Joints are practically non-existent.

Hydrogeological conditions in the upper stopes and drifts in general indicate dripping in places on the rock walls, with two exceptions:

1.- a test hole in the ceiling of one drift allows the passage of a continuous trickle of water estimated at ½ (US) GPM.

2.- the flow of water coming from a raise going to the surface was estimated at 5 (US) GPM.

A few boulders, one to five cubic feet in size, have fallen from an acces drift into a stope. According to management, these rockfalls were caused by the last blasting carried out in this stope some five years earlier.

1.11 MANAGEMENT'S COMMENTS

With regard to surface pillar design, management mentions that the type of rock, fracturing and mining sequence are the main parameters to be considered. The economic zone of the surface pillar should generally be mined at the end of mining operations, especially where the entire pillar is to be recovered. The economic factor has a direct influence on the methods and procedures for mining the pillar; the drilling patterns and the location of the drill holes depend on the content and tonnage of the pillar.

Management considers that the rock mass containing the deposit is competent according to the rock mechanics data and as a result, the stability of the pillars can be evaluated using the beam theory.

MINE #2

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2.0 SUMMARY OF THE VISIT

The mine is composed of several lenses of mineralized (Cu, Zn) massive sulfides in gradation along a length of about 2 400 ft (730 m) and over a total width of 400 ft (122 m). The dip of the formations is 70°S and the slope 70°E.

The upper part of the deposit was worked by open pit to a depth of 640 ft (195 m). There are four (4) parallel lenses at this depth in the eastern section of the mine; in three (3) of them, surface pillars about 50 ft (15 m) thick separate the bottom of the pit from the upper stopes of the mine. Only the walls of the pit are likely to be affected by the stability of these pillars.

The contact points between the walls and the deposit are very marked but irregular. The walls are mainly composed of chlorite schist. The rock mass is fairly fractured but the joints are tight and contain no fill material. In general, the zones of massive sulfides are of better competence than the walls. The Company has done rock mechanics studies and determined the main characteristics of the rock mass.

The mining method used on this property is blasthole stoping with fill. Twenty foot (6 m) transverse pillars are left between the stopes every 130-165 ft (40-50 m).

"In situ" stress measurements have been taken at several levels.

The design calculations of the surface pillars located at the bottom of the open pit mine were based on the beam theory and on the maximum compressive strength of the rock when submitted to a concentration of stresses.

2.1 GENERAL INFORMATION

. Regional Geology

The mining property is situated in the southern part of the Churchill Province or to be exact, in a belt of volcanic rock forming an arc and striking E-W. This group of rocks is composed of a sequence of volcanic lava, tuff, agglomerates, breccia and volcanoclastic sediments.

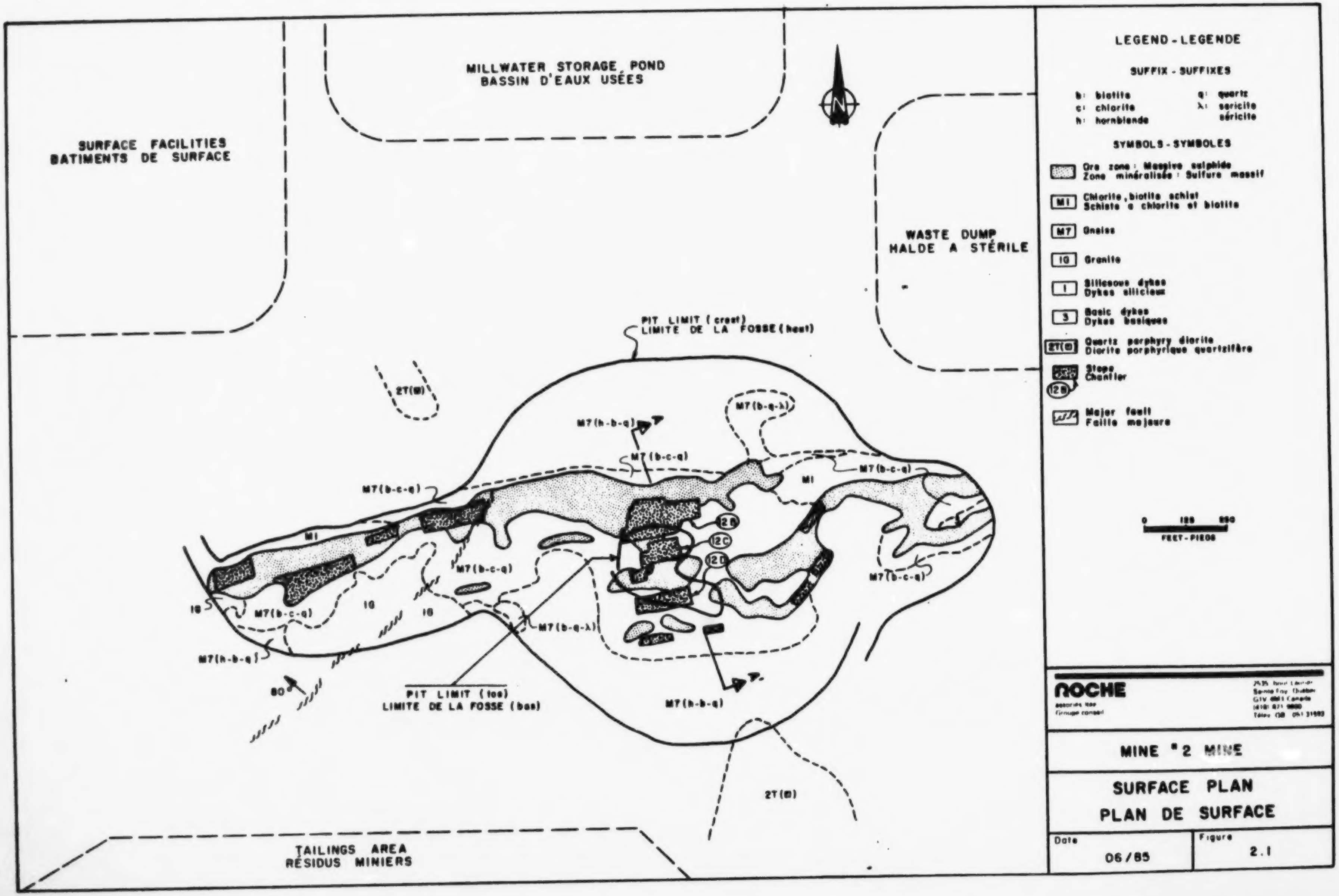
These Precambrian volcanic rocks were considerably altered by regional metamorphism which varies from amphibolite facies to green schist. Finally, this volcanic belt is partially surrounded by metasediments.

. Local Geology

The ore is confined to a series of metamorphosized layers of intermediate volcanic rocks (schist, gneiss) and of volcanoclastic metasediments, with a strike of N70°E and a dip 70°SE. The ore plunges 70° to the east. Dykes of granite, gabbro and diabase intersect the walls and the ore (see Figure 2.1).

. Characteristics

At the surface, the deposit has a total width of about 400 ft (122 m) and a length of about 2 400 ft (730 m). The strike is N70°S and the dip 70°SE; the deposit plunges at 70°NE.


SURFACE FACILITIES
BATIMENTS DE SURFACE
MILLWATER STORAGE POND
BASSIN D'EAUX USÉES
WASTE DUMP
HALDE A STÉRILE
TAILINGS AREA
RÉSIDUS MINIERS
PIT LIMIT (crest)
LIMITE DE LA FOSSE (haut)
PIT LIMIT (toe)
LIMITE DE LA FOSSE (bas)
N
2T(Θ)
2T(Θ)
M7(b-q-λ)
M7(h-b-q)
M7(b-c-q)
M7(b-c-q)
M7(b-c-q)
M7(b-c-q)
M7(b-c-q)
M7(b-c-q)
M7(b-q-λ)
M7(h-b-q)
M7(h-b-q)
M1
M1
1G
1G
1G
1G
12B
12C
12D
80
LEGEND - LEGENDE
SUFFIX - SUFFIXES
b: biotite
c: chlorite
h: hornblende
q: quartz
λ: sericite séricite
SYMBOLS - SYMBOLES
Ore zone: Massive sulphide
Zone minéralisée : Sulfure massif
M1 Chlorite, biotite schist
Schiste à chlorite et biotite
M7 Gneiss
1G Granite
1 Siliceous dykes
Dykes siliceux
3 Basic dykes
Dykes basiques
2T(Θ) Quartz porphyry diorite
Diorite porphyrique quartzifère
Stope
Chantier
12B
Major fault
Faille majeure
0 120 240
FEET - PIEDS

ROCHE
associés ltée
Groupe conseil

2535 [illegible] Laurier
Sainte-Foy, Québec
G1V [illegible] Canada
(418) 871-[illegible]
Télex [illegible] 051 31593

MINE "2 MINE

SURFACE PLAN
PLAN DE SURFACE

Date	Figure
06/85	2.1

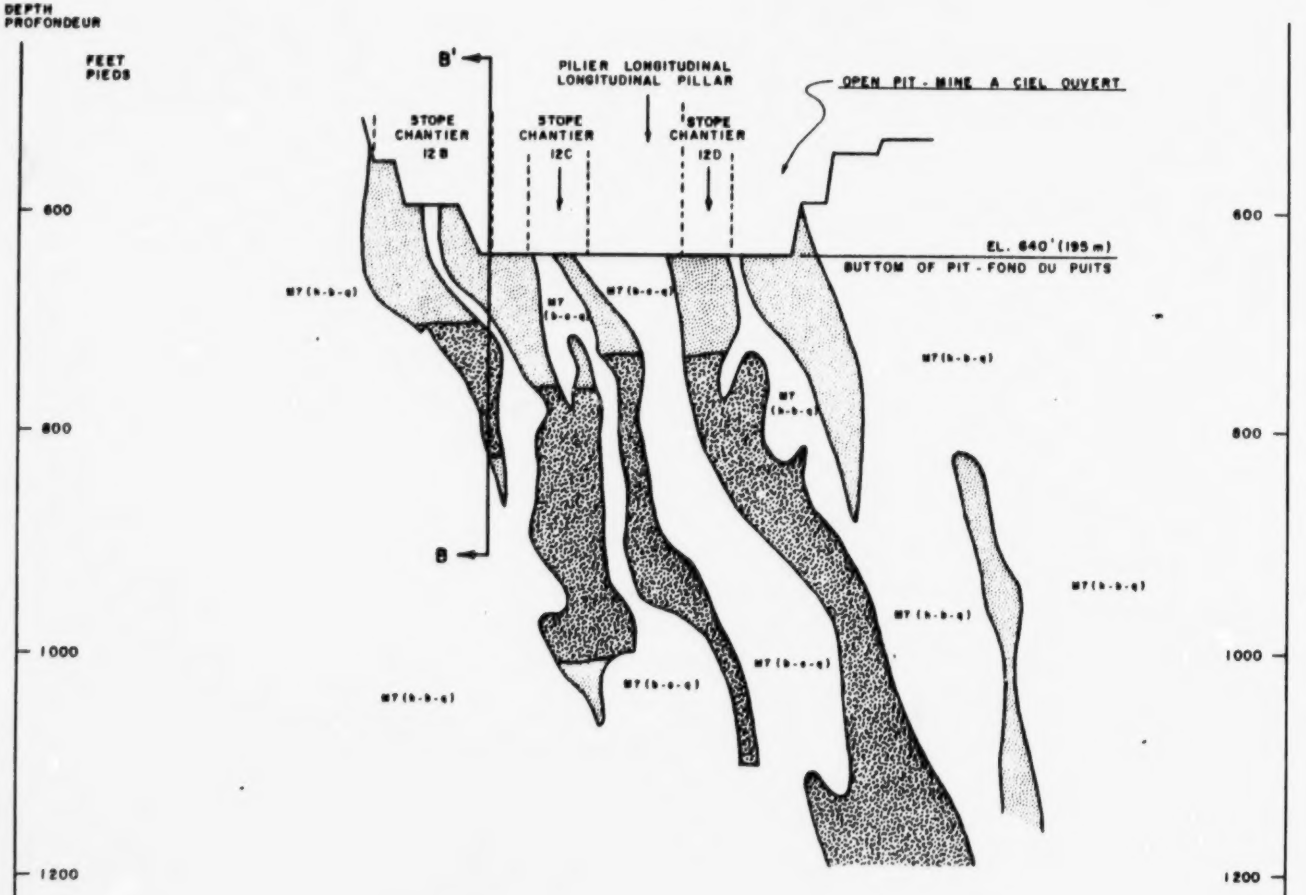
It is composed of lenses of massive sulfides mineralized into copper and zinc in a ratio of 1:1 with traces of gold and silver.

In all, nine (9) parallel ore lenses are arranged vertically in gradation. These lenses are continuous below the 1 000 ft level but gather into two zones in the upper part of the mine. The western zone is made up of a group of five (5) lenses while the eastern zone contains four (4). These lenses vary in width from 23 to 180 ft (7 to 55 m).

The complexity of this arrangement and the irregular shape of the lenses make simplification difficult. Generally, they are of irregular shape both from a planar and cross-sectional point of view and wave or zigzag in the direction of the dip encircling the zones of waste rock as illustrated in figures 2.2 and 2.3.

Since 1971, the Company has mined the upper part of the deposit to a depth of 640 ft (195 m) using the open pit method. Since 1979, it has been operating the underground sector at an extraction rate of 6 000 tons/day.

A series of surface pillars presently exist between the top of some underground stopes and the bottom of the open pit. In all, eleven (11) stopes approach the surface, either in the center of the pit or in the walls. We will, however, concentrate on the group of pillars situated at the bottom of the pit and identified in Figure 2.1 by the numbers 12B, 12C and 12D. Stope 12B will be used as an example.


DEPTH
PROFONDEUR
FEET
PIEDS
600
800
1000
1200
B'
B
STOPE
CHANTIER
12 B
STOPE
CHANTIER
12C
PILIER LONGITUDINAL
LONGITUDINAL PILLAR
STOPE
CHANTIER
12D
OPEN PIT - MINE A CIEL OUVERT
EL. 640' (195 m)
BUTTOM OF PIT - FOND DU PUITS
M7 (h-b-q)
M7 (b-c-q)
M7 (b-c-q)
M7 (h-b-q)
M7 (h-b-q)
M7 (h-b-q)
M7 (h-b-q)
M7 (b-c-q)
M7 (b-c-q)
M7 (h-b-q)
600
800
1000
1200

LEGEND - LEGENDE

SUFFIX - SUFFIXES

b: biotite
c: chlorite
h: hornblende
q: quartz

SYMBOLS - SYMBOLES

░ Massive sulphide
Sulfure massif

M7 Gneiss

▓ Stope
Chantier

0 50 100
FEET - PIEDS

SECTION
COUPE
A - A'

ROCHE
associés ltée
Groupe conseil

2535 boul Laurier
Sainte-Foy Québec
G1V 4M3 Canada
(418) 871 9800
Telex 051 31593

MINE "2 MINE

GEOLOGICAL SECTION
COUPE GEOLOGIQUE

Date	Figure
08/85	2.2

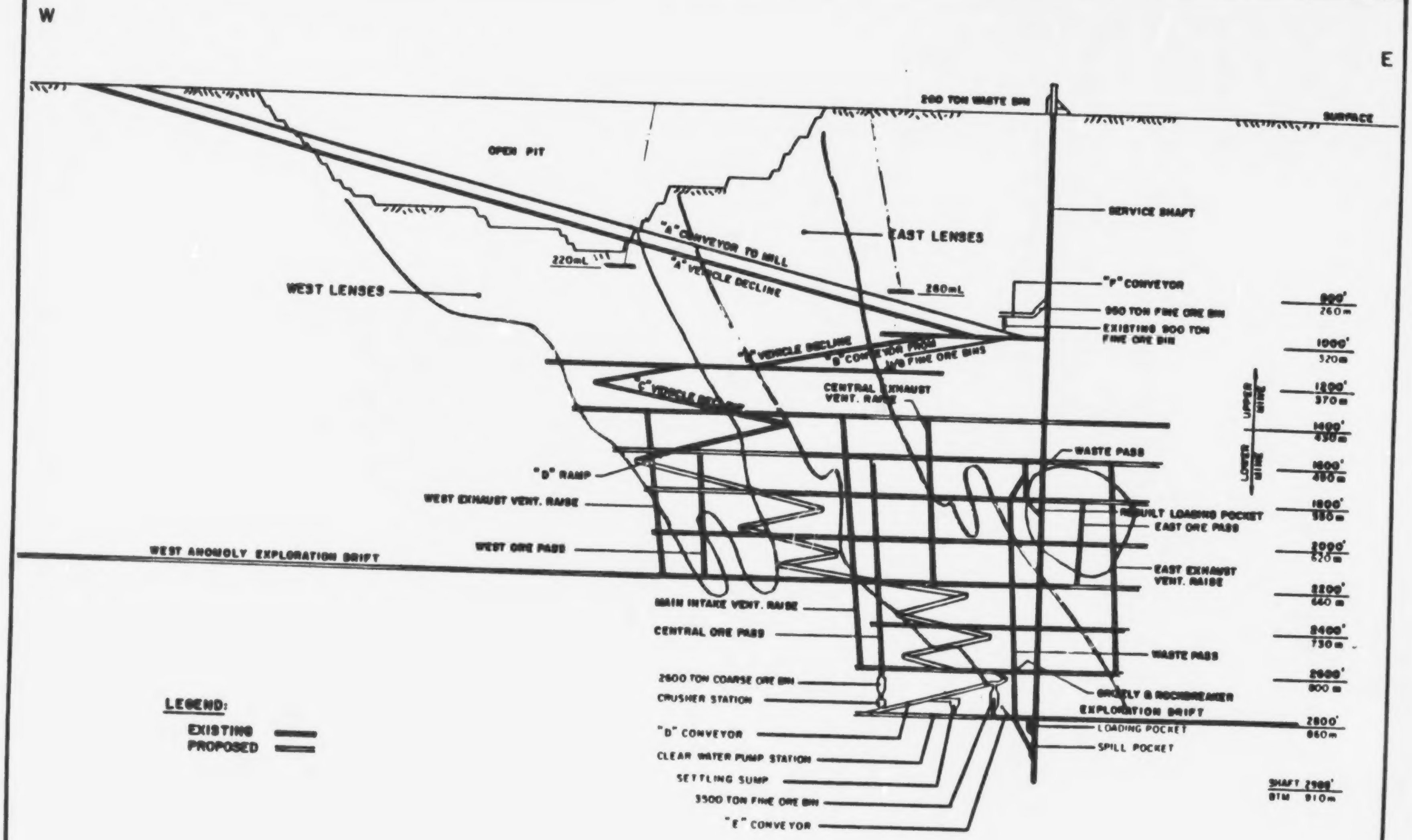

W
E
200 TON WASTE BIN
SURFACE
OPEN PIT
SERVICE SHAFT
EAST LENSES
"A" CONVEYOR TO MILL
"A" VEHICLE DECLINE
220mL
260mL
WEST LENSES
"F" CONVEYOR
900 TON FINE ORE BIN
EXISTING 900 TON FINE ORE BIN
"A" VEHICLE DECLINE
"B" CONVEYOR FROM U/G FINE ORE BINS
CENTRAL EXHAUST VENT. RAISE
"C" VEHICLE DECLINE
UPPER MINE
LOWER MINE
800' 260m
1000' 320m
1200' 370m
1400' 430m
1600' 490m
1800' 550m
2000' 620m
2200' 660m
2400' 730m
2600' 800m
2800' 860m
SHAFT 2980' BTM 910m
WASTE PASS
"D" RAMP
WEST EXHAUST VENT. RAISE
REBUILT LOADING POCKET
EAST ORE PASS
WEST ANOMOLY EXPLORATION DRIFT
WEST ORE PASS
EAST EXHAUST VENT. RAISE
MAIN INTAKE VENT. RAISE
CENTRAL ORE PASS
WASTE PASS
2600 TON COARSE ORE BIN
CRUSHER STATION
GRIZZLY & ROCKBREAKER
EXPLORATION DRIFT
LOADING POCKET
SPILL POCKET
"D" CONVEYOR
CLEAR WATER PUMP STATION
SETTLING SUMP
3500 TON FINE ORE BIN
"E" CONVEYOR
LEGEND:
EXISTING
PROPOSED

Figure 2.3 East-West longitudinal section

Coupe longitudianle Est-Ouest

2.2 MINE ENVIRONMENT

No other mining operation is located near this mine. The surface installations are all located far outside the perimeter of the open pit mine. Only the walls of this pit could be affected by the stability of the surface pillars.

In order to check for movement of the walls, convergence measurements were taken on an annual basis with a "Wild Distomat". As the results indicated displacements ranging from 0.01 - 0.07 ft (0,3 - 2cm), the Company has discontinued the practice.

Finally, the overburden which originally covered the area of the open pit mine has been stripped to about 150 ft (46m) from the present edge of the pit.

2.3 OVERBURDEN

. Studies

We could not gather much information on this aspect. The overburden was evaluated in terms of quality and quantity only for its removal. Some 2.2 million cubic yards (1.7M m^3) of sand and gravel and more than 580 000 cubic yards (443 000 m^3) of peat were removed in order to begin recovery in the open pit mine.

. Stratigraphy and Characteristics

The overburden ranged from 20 to 30 ft (6 to 9 m) thick. It was mainly composed of sand and gravel covered by a layer of peat.

As it was not in the interest of this study to develop this aspect, we have restricted ourselves to these general comments.

2.4 ROCK MASS

. Nature of the Rock

Approaching the footwall of the mine, there is a sequence of almost unaltered, gneiss-type, volcanoclastic rocks. This sequence is further altered by contact with sulfide and is transformed into chlorite and biotite schist as found at the interface with the ore zone and the two walls. The hanging wall is partly composed of metasedimentary, volcanoclastic rocks and granite intrusions.

. Structural Geology

Over the whole of the mine, two major families of joints have been mapped. The strike of the joints of the first family varies between 45 - 90° and the dip is 75°S. They are thus parallel to the average strike of the local formations and ore lenses.

The second family strikes at an angle of 0 - 20° and is relatively flat, dipping south. Moreover, a substantial structure, especially obvious in the hanging wall, cuts almost horizontally across the formations.

The joints are generally spaced at 3 to 6 ft (1 to 2 m) and are continuous across the different rock formations. They are tight, contain no fill material and show a smooth surface. A major fault located in the western zone cuts across the deposit with an dip of 45° (see Figure 2.1) and its slope is 80°N. This fault is filled with chlorite and biotite schist. Finally, a shearing zone follows the north interface of the deposit, descending at 80°S. The foliation which occurs in the rock mass is sub-parallel to the bedding of the formations.

. Characteristics

Table 2.1 summarizes the principal geomechanical characteristics of the rocks. It is evident that the schist in the footwall is relatively less competent than the other rocks; also, the lenses in the eastern zone of the mine are more competent than those in the western zone.

During the initial development period of the mine, the Geology Department used a point load test on a continuous basis. A series of simple compressive strength tests were done in the laboratory to relate the load point index to the strength of different types of rock. Generally, the sample cores were 1.06 in. in diameter. The sequence of the identification work on the rock mass was as follows:

1) systmatic load point test
2) calculation of the index (Is)
3) determination of the compressive strength value
4) assigning of a qualitative value
5) transfer of the results to layouts for each level
6) transfer of the data to the Engineering Department

The mine had established its own rock classifications based on the compressive strength values. These classifications were as follows:

ROCK CHARACTERISTICS

CARACTÉRISTIQUES DE LA ROCHE

TABLE 2.1

TABLEAU2.1

LOCATION EMPLACEMENT		FOOT WALL ÉPONTE INFÉRIEURE		OREBODY GISEMENT	HANGING WALL ÉPONTE SUPÉRIEURE
ROCK TYPE TYPE DE ROCHE		Quartzitic rocks Gneiss quartzitiques	Chlorite/biotite schist Schistes à chlorite/biotite	Massive sulphides Sulfures massifs	Volcaniclastics sediments Sédiments volcanoclastiques
DENSITY DENSITÉ		2.91	2.91	3.89	2.91
COMPRESSIVE STRENGTH RÉSISTANCE EN COMPRESSION	psi x 10^3 (MPa)	7 (48)	16 (110)	13 (90)	19 (131)
SHEAR STRENGTH RÉSISTANCE AU CISAILLEMENT	psi x 10^3 (MPa)	-	-	-	-
TENSILE STRENGTH RÉSISTANCE EN TENSION	psi x 10^3 (MPa)	-	-	-	-
POINT LOAD STRENGTH INDICE DE DOUBLE POINCONNEMENT	psi x 10^3 (MPa)	-	-	-	-
POISSON'S RATIO RAPPORT DE POISSON		0.12	0.34	0.20	0.19
YOUNG'S MODULUS MODULE DE YOUNG	psi x 10^6 (GPa)	7.2 (50)	7.9 (55)	12.8 (82)	11.1 (77)
RQD %		-	-	-	-
GEOMECHANICAL CLASSIFICATION CLASSIFICATION GÉOMÉCANIQUE	(CSIR) OUEST EST	55 70	55 70	60 80	70 70

Rock quality	Compressive strength (lbs/in^2	MPa
very poor	0-7500	0-52
poor	7500-12000	52-83
intermediate	12000-16000	83-110
good	16000-25000	110-172
very good	25000 and up	172 and up

According to the persons interviewed, it appears that this classification system was useful during the first years of exploitation of the underground mine. In fact, since the personnel is still not familiar with the terrain, these classifications facilitate the evaluation of the competence of new production zones and the planning of appropriate mining methods.

On the other hand, the Company does not calculate the R.Q.D. of the rock but indicates on geological cross-sections the number of fractures present in a five ft (1.5m) length of diamond drilled core. The CSIR geomechanical classification of the rock was also used for a certain period.

2.5 HYDROGEOLOGICAL CONDITIONS

. Overburden

Around the open pit mine, a canalization ditch intercepts stream water. We observed very little water on the walls of the pit.

. Rock Mass

There is almost no water in this mine. The average pumping rate is 300 GPM (22 L/s).

2.6 MINING OPERATIONS

. Mining methods

Since the beginning of operations, about fifty (50) stopes have been mined using blasthole stoping with fill. About 30% of the stopes were drilled with 2 in (51 mm) holes and the rest by drills equipped with 6½ in (165 mm) bits. The stoping areas vary in width and length according to the shape and ore-content of the lenses as well as the quality of the terrain. Typical stope dimensions are follows:

Width : 23 - 100 ft (7 - 30m)
Height : 200 ft (61 m)
Length : 130 - 165 ft (40 - 50m)
Slope : 70°

A series of transverse pillars 20 ft (6m) wide are left between the stopes in the ore zone. Also, according to the position of the lenses, longitudinal pillars are formed by the waste rock.

. Operating Conditions

Overall on the property, the extraction rate is about 80% and dilution, mainly coming from the walls of the stopes, is 15 to 20% of the theoretic tonnage.

The mine is worked from top to bottom. The filling of the stopes sometimes requires 1 to 2 years. The powder factor of this operation is about 0.7 lb/ton (0.3 kg/t).

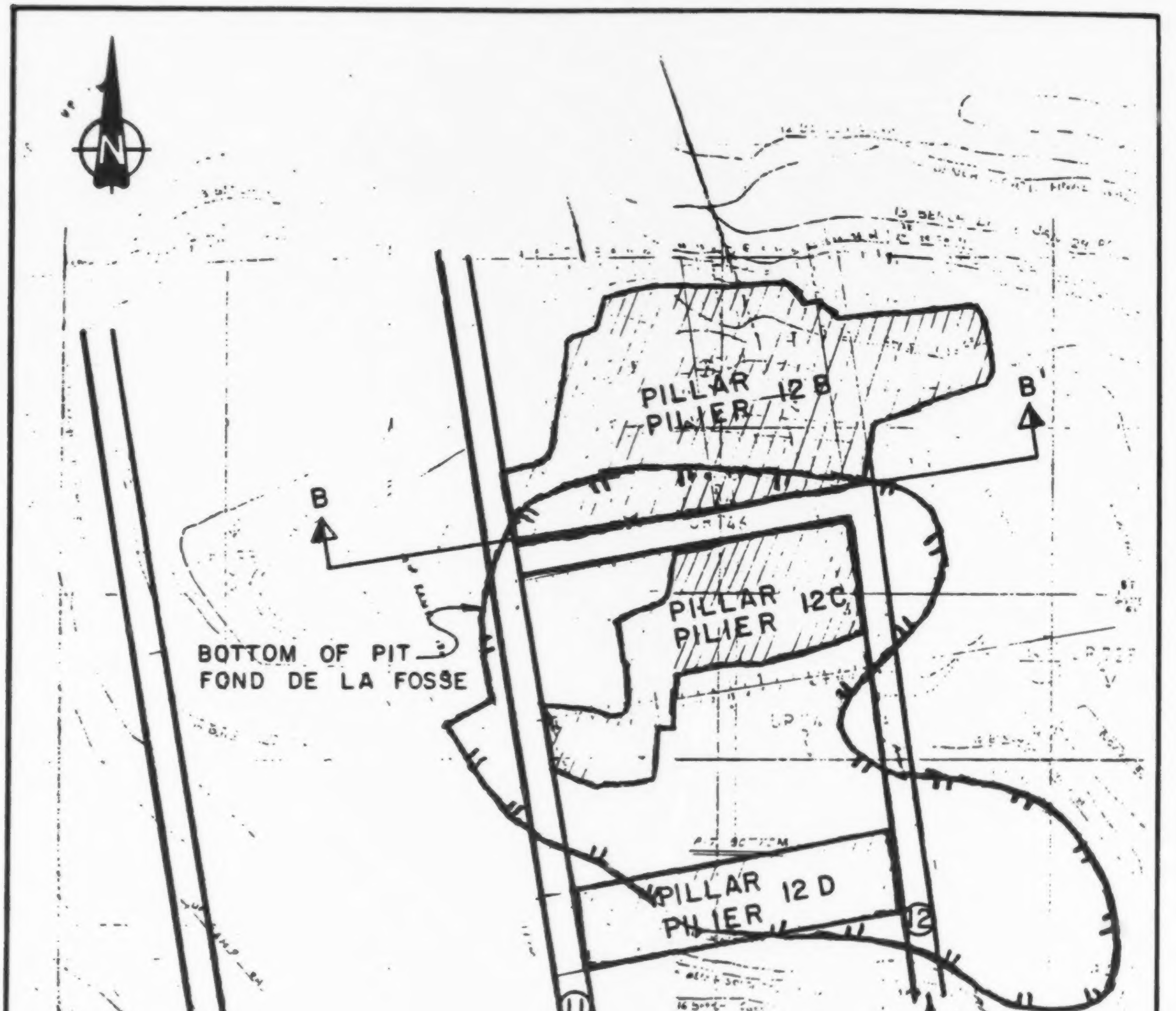
2.7 SUPPORT AND REINFORCEMENT METHODS

. Primary support

The walls are supported by a series of transverse pillars 20 ft (6 m) thick left between the stopes inside the ore zone. These pillars are lined up over the entire width of the deposit thus crossing the series of lenses in the upper levels. Also, depending on the arrangement of the lenses, longitudinal pillars are left in the waste rock. These contribute to the stability of the rock mass by reducing the span of the surface pillar zone. A sketch of the general layout of these pillars appears in Figure 2.4 around the sector covered by the surface pillars under study (pillars 12B, 12C and 12D).

. Filling and Reinforcement

The fill introduced into the drawn stopes is composed of classified, uncemented tailings. Locally, the development drifts are reinforced with conventional bolts. Some swellex-type bolts of varying length have been used at the drawing points.



N
PILLAR 12B
PILIER 12B
B
B'
PILLAR 12C
PILIER 12C
BOTTOM OF PIT
FOND DE LA FOSSE
PILLAR 12D
PILIER 12D
10
11
12
RIB PILLARS
PILIERS TRANSVERSEAUX

FIGURE 2.4 PILLAR GEOMETRY

GEOMETRIE DES PILLIERS

2.8 MONITORING PROGRAM(S)

Four (4) series of measurements of the natural stresses in the rock mass were taken at this mine, at levels 260, 340, 400, and 600 m: a 5th series is planned for level 800 (eastern sector). The testing technique in all cases was the over-coring method, but different instruments were used. More than 25 readings were measured with biaxial, doorstopper-type tension gauges and (7) measurements were taken with CSIRO-type triaxial load cells. Only the latter readings taken at level 600 m are reliable.

The readings were correlated to establish a definition of the state of the natural stresses as follows:

Stress	Value	Direction	Dip
σ_1	$2.5\sigma v$	340°	-20°
σ_2	$1.2\sigma v$	70°	0°
σ_3	$0.3\sigma v$	160°	-70°

$\sigma 1$ = major principal stress
$\sigma 2$ = intermediate principal stress
$\sigma 3$ = minimum principal stress
σv = 1.2 psi/ft (0.0272 MPa/m)

The deformation modulus and the Poisson's ratio used for the tests were 10.1×10^6 psi (69.46 GPa) and 0.18 respectively. The results were used by the mine's rock mechanics group to evaluate the behavior of the stopes and/or the pillars of the lower levels of the property (+ 340m).

. Displacement Measurements

No displacement measurements have been taken right at the surface pillar level (level 200 m). However, at levels 340 m and 400 m, instruments have been installed in the stopes to study the transfer mechanisms of the stresses and the displacement of the walls as mining progresses. This experiment could certainly prove useful when the time comes for extraction of the surface pillars.

. Other Programs

No other program related to the surface pillars is currently in effect.

2.9 SURFACE PILLAR DESIGN

. Personnel Involved

Figure 2.5 shows an organization chart of those likely to be involved in pillar design. At this mine, the Geology Department provides most of the structural and economic data necessary to the operations and approves the planning done by the Engineering Department. The services of an outside consultant are used as required.

. Chronology

The following is an overall summary of operations on this property:

i) Open pit mining to a depth of 640 ft (195 m) with respect to surface.

ii) Mining of the underground stopes, temporarily leaving surface pillars between the bottom of the pit and the underground mine. These pillars are identified in Figure 2.1 by the numbers 12B, 12C and 12D.

iii) Surface pillars will be mined to the bottom of the pit.

Since the sizing of the surface pillar in stope 12B was the subject of an in-depth study, it will be used as an example to summarize the Company's policy in this field. It should be noted, however, that the pillars in stopes 12C and 12D are slightly thicker than in stope 12B.

ORGANIZATION CHART - PILLARS DESIGN
ORGANIGRAMME - CONCEPTION DES PILIERS

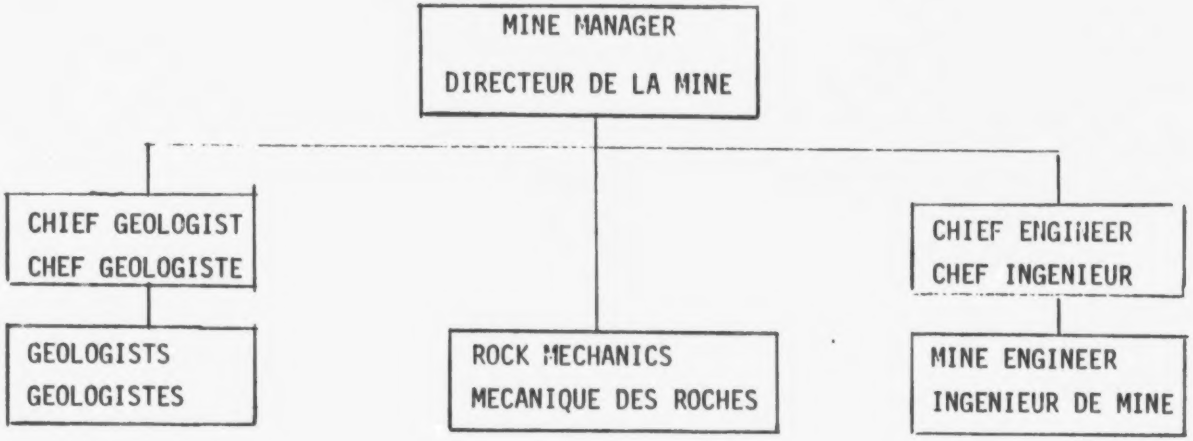

MINE MANAGER
DIRECTEUR DE LA MINE
CHIEF GEOLOGIST
CHEF GEOLOGISTE
GEOLOGISTS
GEOLOGISTES
ROCK MECHANICS
MECANIQUE DES ROCHES
CHIEF ENGINEER
CHEF INGENIEUR
MINE ENGINEER
INGENIEUR DE MINE

Figure 2.5

. Design Factors

The first consideration for the design was the temporary use of the 12B surface pillar. From the beginning, the Company intended to mine this pillar. This did not, however, remove the necessity of designing it adequately and safely.

Among other things, it had to provide stability to the walls of the open pit mine which are resting on it. Calculataions were made on a longitudinal slice of this surface pillar that was supported by two transverse pillars, as shown in Figure 2.6.

The following hypotheses were formulated with respect to rupture modes:

i) Ruptures are caused by a high tension stress at the center of the pillar, due to the flexion of the rock.

ii) Ruptures are caused by a concentration of the compressive stress at the extremities of the surface pillar, resulting in the caving and total deterioration of the extremities of the surface pillar; this in turn causes a loss of strength and the caving of the whole of the central part of the pillar.

The study also looked into the ideal shape that the top of the pillar should take. Trimming the roofs of the stopes to an arch shape is very difficult and would have

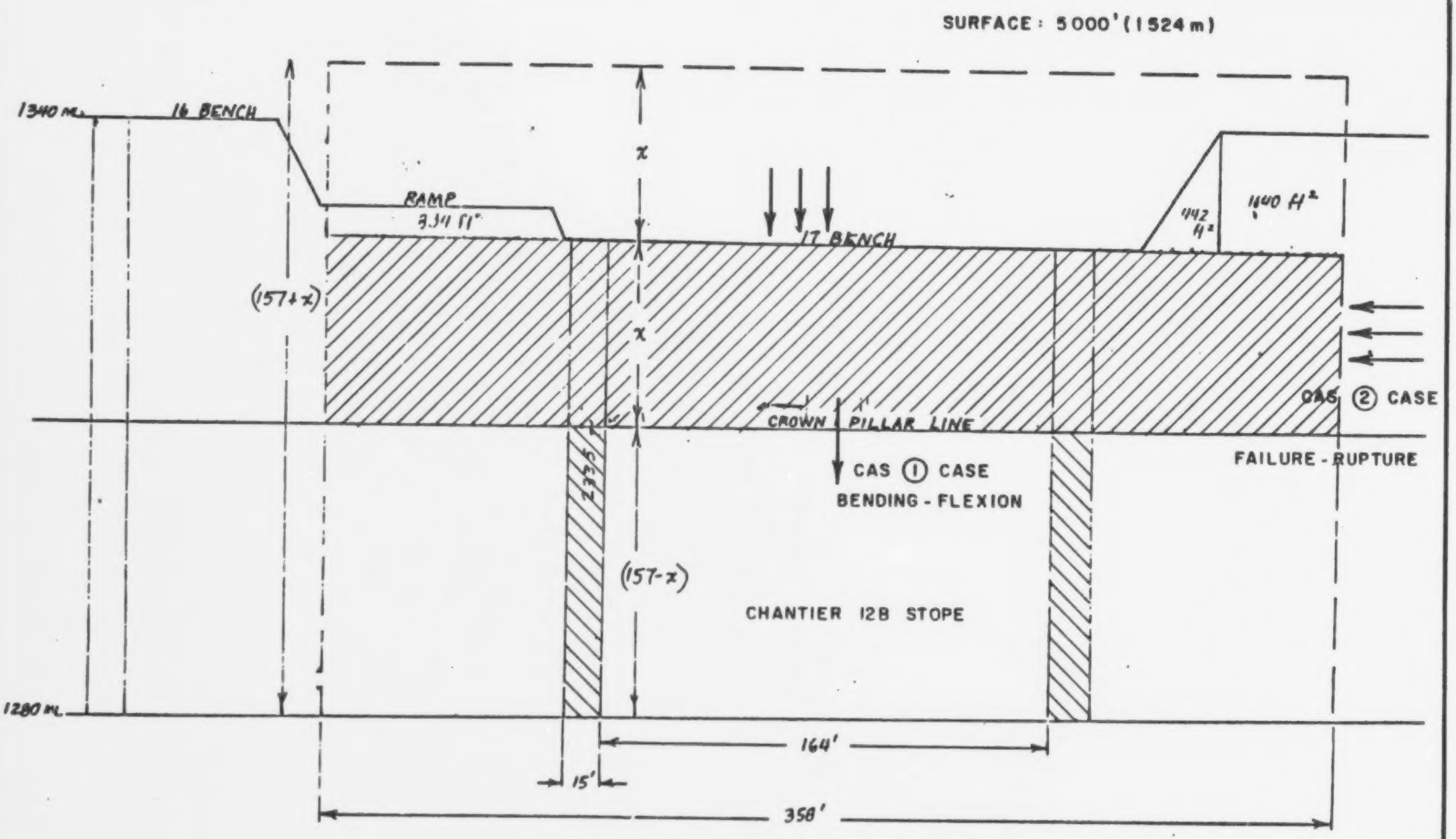

SURFACE : 5000'(1524 m)
1340 m.
16 BENCH
RAMP
3.3'4 51°
x
x
(157+x)
17 BENCH
1142 ft²
1100 ft²
CROWN PILLAR LINE
CAS ② CASE
FAILURE - RUPTURE
CAS ① CASE
BENDING - FLEXION
2335
(157-x)
CHANTIER 12B STOPE
1280 m.
164'
15'
358'

Fig.2.6 : B-B' Section. Calculation example
Coupe B-B'. Exemple d'un calcul

required a height ranging from 80 ft (24 m) to 100 ft (30 m) meaning that a large and unjustifiable quantity of ore would be abandonned. It was therefore recommended that the roof be left flat.

The first method of calculating the thickness of the surface pillar uses standard formulae for beam calculation; as shown in Figure 2.6, the beam is supported by two pillars 164 ft (50 m) apart. It lies equidistant between two neighbouring stopes; this determines its total mass. The stresses operating at this level were evaluated at 4 000 psi (28 MPa) and a safety factor of 1.5 was used on the results of the calculations. In other words, the unknown factor to be determined was the thickness of the surface pillar (x), or of the beam studied; once this thickness was ascertained, the results were multiplied by 1.5.

Several cases of different geometry were calculated in this manner. One of these cases even took into account the presence of 50 ft (15m) of water in the bottom of the pit. The results varied from 12.4 ft (3.8 m) to 31.9 ft (9.7m).

The second method of calculation used bearing area calculations to determine the surface of pillars necessary to withstand the stresses encountered. The author assumes that the openings left around the surface pillar increase the load to be supported by a factor of 3.57. Again, using the multiplication factor of 1.5, the thickness of the surface pillar computed was from 39 ft (12M) to 57 ft (17m).

After analysis and weighting all these results, the surface pillar of the stope 12B was designed for a thickness (x) of 50 ft (15m).

. Pillar dimensions

Table 2.2 summarizes the dimensions of the surface pillars studied (12B, 12C and 12D, illustrated in Figure 2.4). Note that all the underlying stopes have been filled.

DIMENSIONS OF SURFACE CROWN PILLARS

DIMENSIONS DES PILIERS DE SURFACE

TABLE 2.2
TABLEAU 2.2

DIMENSIONS		PILLARS - PILIERS							
		#1	#2	#3					
. THICKNESS: EPAISSEUR:									
- WATER BODY PLANS D'EAU	feet-pi. (m)	-	-	-					
- OVERBURDEN MORTS-TERRAINS	feet-pi. (m)	-	-	-					
. SURFACE CROWN PILLAR: PILIER DE SURFACE:									
- THICKNESS EPAISSEUR	feet-pi. (m)	50 (15)	100 (30)	90 (27)					
- WIDTH LARGEUR	feet-pi. (m)	100 (30)	75 (23)	45 (14)					
- LENGTH LONGUEUR	feet-pi. (m)	164 (50)	164 (50)	164 (50)					
- THICKNESS/WIDTH RATIO RAPPORT EPAISSEUR/LARGEUR		0,5	1,33	2,0					
. STOPE HEIGHT HAUTEUR DU CHANTIER	feet-pi. (m)	360 (110)	360 (110)	360 (110)					
. FILL HEIGHT HAUTEUR DU REMBLAI	feet-pi. (m)	360 (110)	360 (110)	360 (110)					

2.10 VISUAL EVALUATION OF THE SURFACE PILLAR(S)

The visual evaluation of the surface pillars is carried out from the bottom of the pit and from a few lateral drifts.

There is no sign of subsidence to indicate that the rock mass has moved. There is water present at the bottom of the pit, a sign of the quality of the terrain.

In the drifts situated below and around the surface pillars, the joints are still closed and there is no sign of flowing water.

The Company is presently preparing to recover these pillars. The accesses for drilling are stable and present no major support problems. The design approach followed by the Company seems to have produced the expected results.

2.11 MANAGEMENT'S COMMENTS

Relative to the surface pillars, the Company wonders at what point in the exploitation of a mine one should recover these pillars - if that is possible. They feel that the design of such pillars should take economic factors into account.

In general, the Company feels that the basis of any rock mechanics program should be conducted on-site, if possible. In this way, instruments can be placed in the surface pillars separating the bottom of the pit from the upper stopes of the mine to detect any advance signs of instability.

They admit that an integrated evaluation program of the rock mass is a desirable tool for an underground operation.

MINE #3

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3.0 SUMMARY OF THE VISIT

The mining site is located in a series of metavolcanic and metasedimentary rocks. The walls are composed of biotite schists and ultramafic breccial sulfides containing nickel.

The vein of the deposit varies in thickness from 10 to 150 ft (3 - 45 m) and has an average dip of 65°E.

Since operations began, there has been no evidence of settling in the surface.

A lake which covers the surface pillars has nearly been dewatered and currently (summer 85) a dredge is removing the overburden to allow for open pit mining of the pillars.

Approximately 50 drill-holes have been bored to define soil characteristics and to establish the soil-rock interface.

Soil depth varies between 70 and 170 ft (21 - 52 m) and is composed of organic deposits, clay, silt, sand and gravel.

Two types of folds and three sets of joints have been identified in the rock mass. An extensive study (program) was set up in collaboration with an external consultant; this study reviews in detail the rock mass characteristics and the influence of future open pit mining on underground operations.

The upper stopes have been exploited using the cut-and-fill method and several wall pillars have been left in the larger stopes. Bolting has been done and bolts are generally anchored perpendicular to the schistosity or foliation.

"In situ" compressive strength values taken at the upper stope levels provide a horizontal to vertical stress ratio of approximately 4.

The surface pillar design has been approached conservatively given the presence of a lake and the considerable thickness of the soil located above the deposit. Mine management has chosen an average rock thickness of 240 ft (73 m) to protect the mine. The ore which has been temporarily left in the surface pillars will be extracted by the open pit method and the final bench mined from underlying stopes.

3.1 GENERAL INFORMATION

. Regional Geology

The mining site is located in the Churchill Province in close contact with the Superior Province. In the NW-SE direction the following sequences are found: metasedimentary and metavolcanic rocks, gneiss, granite intrusions, peridotite, serpentite, metasediments (host rock) and gneiss toward the south-east. The deposit is located in a regional nickel belt or, more precisely, along a 1 000 ft (300 m) wide syncline. The surrounding Precambrian rock has been altered to metamorphic amphibolite facies.

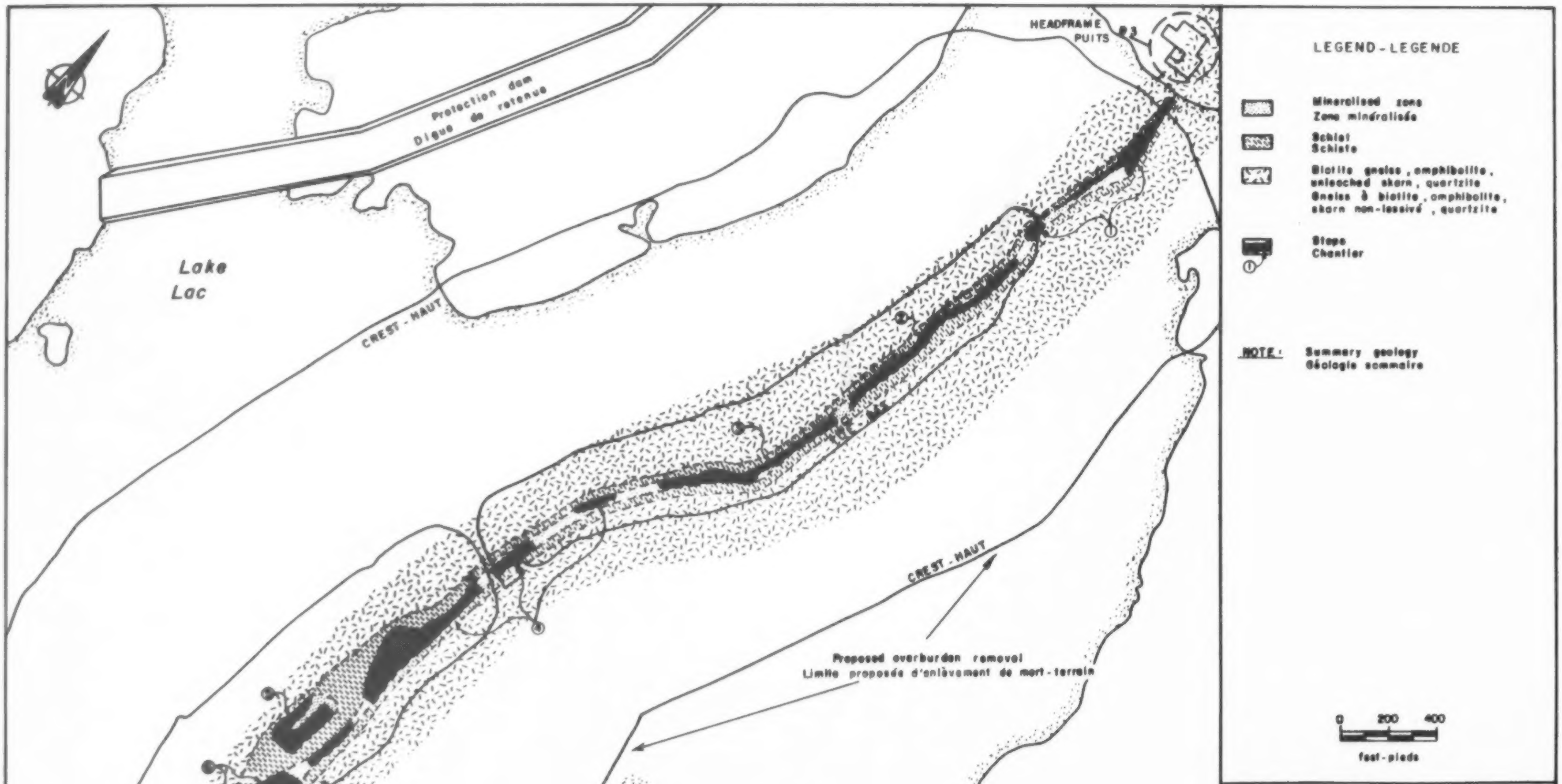
. Local Geology

The orebody is contained in a biotite schist surrounded by a rock sequence composed of quartz, gneiss, amphibolite and unaltered skarn (see figures 3.1 and 3.2). Leached skarn is found on the side of the hanging wall. Several peridotite intrusions have been noted across the ore zone.

. Characteristics of the Deposit

The orebody is an ultramafic breccial sulfide deposit containing nickel in a continuous vein of variable thickness. The dimensions of the deposit are as follows:

Length	Width	Depth
16 400 ft	10 - 150 ft	4 430 ft
(5 000 m)	(3 - 45 m)	(1 350 m)


HEADFRAME
PUITS #3
Protection dam
Digue de retenue
Lake
Lac
CREST-HAUT
CREST-HAUT
CREST-HAUT
Proposed overburden removal
Limite proposée d'enlèvement de mort-terrain
Lake
Lac
LEGEND-LEGENDE
Mineralised zone
Zone minéralisée
Schist
Schiste
Biotite gneiss, amphibolite, unleached skarn, quartzite
Gneiss à biotite, amphibolite, skarn non-lessivé, quartzite
Stope
Chantier
0 200 400
feet-pieds

NOTE: Summary geology
Géologie sommaire

NOCHE

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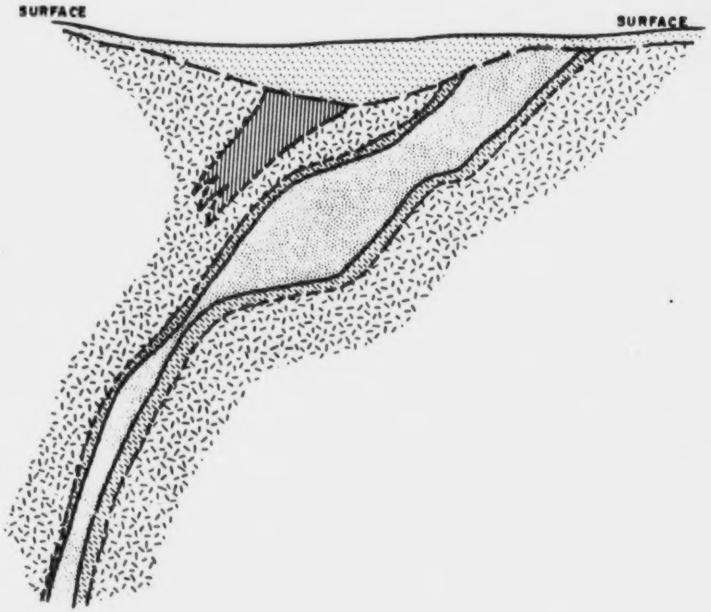
MINE #3 MINE

SURFACE PLAN
PLAN DE SURFACE

Date	Figure
07/85	3.1



LEGEND - LEGENDE

░	Ore zones Zones minéralisées
▨	Biotite gneiss, amphibolite, unleached skarn, h.w. and f.w. quartzite. Gneiss a biotite, amphibolite, skarn non-lessivé, éponte de quartz.
▨	Hanging wall: schist Eponte supérieure: schiste
▥	Leached skarn Skarn partiellement dissout
▨	Footwall: schist Eponte inférieure: schiste
░	Overburden Mort-terrain

NOTE: Schematic section
Coupe schématique

ROCHE
[illegible]
Groupe conseil

[illegible]
Sainte-Foy [illegible]
[illegible] Canada
(418) [illegible]
Telex [illegible]

MINE # 3 MINE

GEOLOGICAL SECTION
COUPE GEOLOGIQUE

Date 06/85
Figure 3.2

The average dip of the deposit is 65°E and the surface pillars strike in a NS direction (see Figure 3.1).

Nickel ore production is continuous, and approximately 6 500 t are extracted daily.

3.2 MINE ENVIRONMENT

All surface pillars lie beneath a lake. On the surface, a protection dam parallels the main pillar line at an approximate distance of 1 600 ft (490 m).

The pillars terminate approximately 50 ft (15 m) from a shaft situated north of the lake (see Figure 3.1).

No surface settling has been observed.

3.3 OVERBURDEN

. Studies

In 1981, approximately 50 holes were drilled beneath and around the lake. Piezometers and geotechnical tests were conducted during these drillings. The land profile and geotechnical properties were determined by an external consultant. In the forseeable future, management intends to exploit the surface pillars by the open pit method; studies have already been undertaken. A second external consultant studied the impact that this future operation would have on underground operations. The zone studied has been limited to a depth ranging from 0 - 1 000 ft (305 m). The general procedure that the Company intends to follow is based on recommendations and defined in section 3.4 and 3.9.

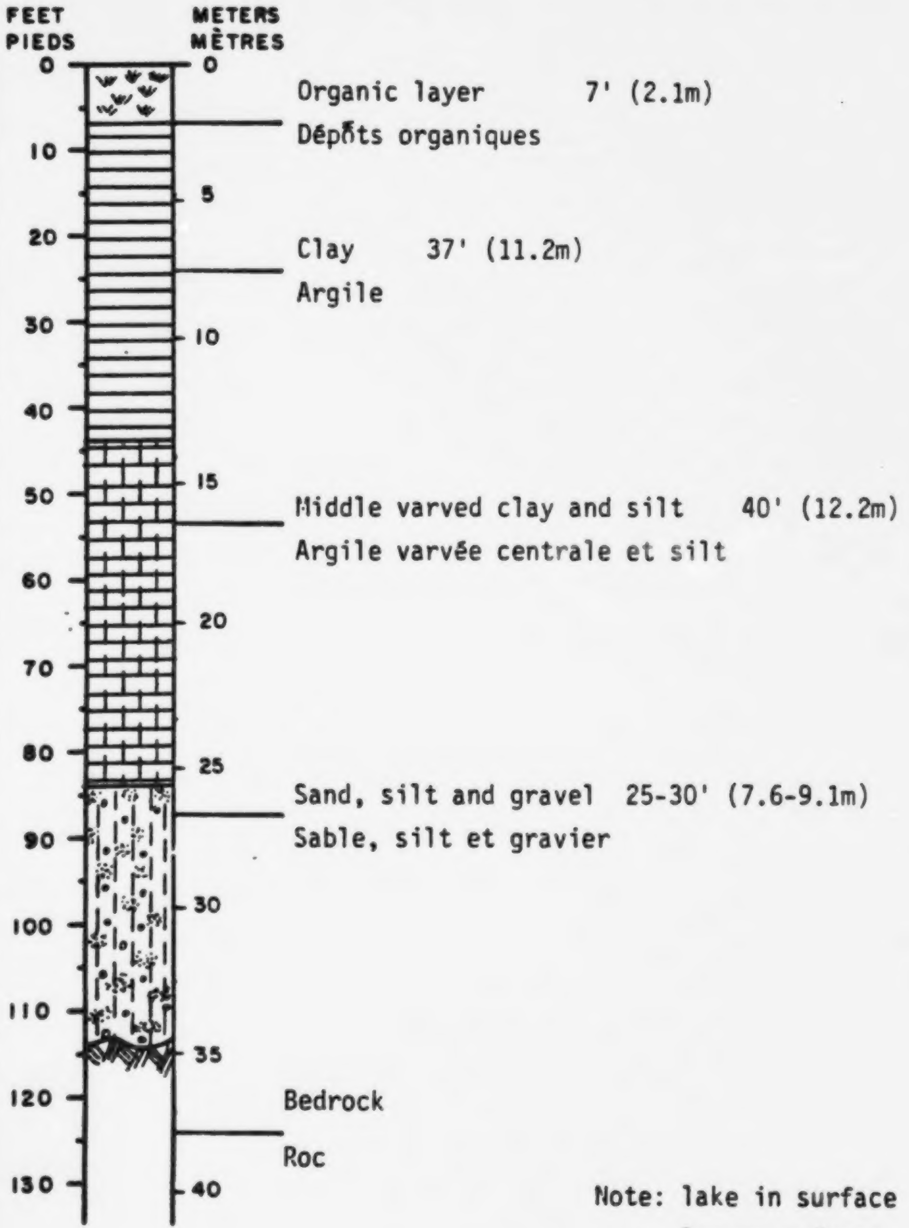
. Stratigraphy and Characteristics

The simplified stratigraphy obtained along the deposit's longitudinal axis is shown in Figure 3.3.

The dewatering of the lake is near completion and a dredge is working to remove the overburden. Currently the water level measures approximately 10 ft (3 m) and the soil thickness beneath the lake varies between 70 and 170 ft (21 - 52 m). The large quantity of clay has made it necessary to devise gentle slopes to avoid landslides.

Table 3.1 gives some characteristics of the soil studied.

SOIL STRATIGRAPHY
STRATIGRAPHIE DU SOL


FEET
PIEDS
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MÈTRES
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5
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20
25
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35
40
Organic layer 7' (2.1m)
Dépôts organiques
Clay 37' (11.2m)
Argile
Middle varved clay and silt 40' (12.2m)
Argile varvée centrale et silt
Sand, silt and gravel 25-30' (7.6-9.1m)
Sable, silt et gravier
Bedrock
Roc

Note: lake in surface : 10' (3m) depth
lac en sufrace : 10' (3m) de profondeur

ROCHE associés ltée Groupe-conseil 2535, boul Laurier, Sainte-Foy, Québec G1V 4M3 Canada (418) 871 9800 Télex QBC 051 31583	**MINE # 3 MINE**	**Date** 07-1985	**Figure** 3.3

SOILS CHARACTERISTICS

CARACTÉRISTIQUES DES SOLS

TABLE: 3.1
TABLEAU: 3.1

PARAMETERS PARAMÈTRES		CLAY ARGILE	SILT SILT	SAND & SILT SABLE & SILT	GRAVEL GRAVIER	CLAY & SILT ARGILE & SILT
UNIT WEIGHT POIDS VOLUMIQUE	lb/ft^3 (kN/m^3)	110 (17)		130 (20)		110 (17)
LIQUID LIMIT LIMITE DE LIQUIDITÉ	%	50-70		-		-
PLASTIC LIMIT LIMITE DE PLASTICITÉ	%	20-30		-		-
WATER CONTENT TENEUR EN EAU	%	20-70		-		-
APPARENT COHESION COHÉSION APPARENTE	lb/ft^2 (kN/m^2)	400-800 (19-38)		-		600-1200 (29-58)
EFFECTIVE COHESION COHÉSION EFFECTIVE	lb/ft^2 (kN/m^2)	-		-		-
APPARENT ANGLE OF FRICTION ANGLE DE FROTTEMENT APPARENT		-		-		-
SPT BLOW COUNT NOMBRE DE COUPS SPT		10-60 $\overline{X} = 30$		10-50 $\overline{X} = 30$		20-80 $\overline{X} = 40$
COEFFICIENT OF PERMEABILITY COEFFICIENT DE PERMÉABILITÉ	$\times 10^{-7} cm/s$	-		-		3-500

3.4 ROCK MASS

The rock mass containing the deposit can be described as follows:

Footwall : biotite schist and peridotite
Deposit : massive sulfides
Hanging wall : biotite schist, peridotite, leached skarn

Some leached skarn, found in the hanging wall is, however, competent according to management.

. Structural Geology

Two types of faults characterize the shearing zone located on the mining site.

	Strike	Dip
1st type :	N80°E	80°NW
2nd type (minor) :	N80°E	45°SE

Three sets of joints have been studied and evaluated according to the criteria detailed in the NGI classification. Tables 3.2 and 3.3 summarize the facts gathered concerning these sets. Occasionally, milonite is also found in the wall fractures near the orebody. The orebody-wall interface is solid and no displacement has been noted.

Natural stress measurements have been taken at level 400 using USBM and CSIRO load cells. The horizontal to vertical stress ratio varied around 4:

σh = 1.7 - 2.3 KSI (12 - 16 MPa)
σv = 0.4 - 0.6 KSI (3 - 4 MPa)

TABLE: 3.2
TABLEAU: 3.2

JOINTS SET
FAMILLES DE JOINTS

Parameters Paramètres	#1	#2	#3
Length (ft) Longueur(m)	164 (50)	7 (2)	16 (5)
Spacing (ft) Espacement (m)	1,3 (0,4)	2,0 (0,6)	7,5 (2,3)
Aperture (ft) Ouverture (m)	tight serré	tight serré	tight serré
Infilling Matériaux de remplissage(1)	silica, carbonate, graphite, mica silice, carbonate, graphite, mica		
Surface roughness Rugosité des joints	rough or irregular to slickensided, undulating rugueux ou irrégulier à glissant, ondulé		
Joint water pressure Pression d'eau	dry or minor inflow sec ou écoulement mineur		
Joint alteration Altération	slightly altered légèrement altéré		
Stress reduction factor Facteur réduction de contraintes	medium stress contrainte moyenne		

(1) Ces matériaux peuvent atteindre jusqu'à 1 ou 2 mm d'épaisseur.

. Characteristics

A rock mechanics program has recently been implemented in collaboration with the Company's technical personnel and an external consulting firm. This program is based principally on the knowledge of the rock mass and the prediction of its performance when exposed to mining operations. The program extends over a twelve-month period and covers the following aspects:

- . geology
- . material properties
- . stress fields
- . mine performance
- . geomechanical model
- . open pit mine analysis
- . mathematical model
- . analysis of the effects of the open pit on underground operations.

The characteristics of the rock mass are outlined in Table 3.3. The biotite schist's compressive strength varied according to the strike of foliation:

Foliation strike in relation to applied force	Compressive strength
<50°	10 KSI (70 MPA)
50-70°	15 KSI (104 MPA)
>70°	20 KSI (138 MPA)

The basic angle of friction for the surrounding rock is estimated at 20°.

The R.Q.D. values are calculated by a geologist. These figures are obtained rapidly with a minimum of

ROCK CHARACTERISTICS

CARACTÉRISTIQUES DE LA ROCHE

TABLE 3.3

TABLEAU 3.3

LOCATION EMPLACEMENT		FOOT WALL ÉPONTE INFÉRIEURE		OREBODY GISEMENT	HANGING WALL ÉPONTE SUPÉRIEURE
ROCK TYPE TYPE DE ROCHE		Biotite gneiss, amphibolite, skarn, quartzite Gneiss à biotite, amphibolite, skarn, quartzite	Biotite schist Schiste à biotite	Massive sulphides Sulfures massifs	Biotite schist Schiste à biotite
DENSITY DENSITÉ		2,65	2,7	3,9	2,7
COMPRESSIVE STRENGTH RÉSISTANCE EN COMPRESSION	psi x 10^3 (MPa)	20-22 (135-153)	10-20 (70-138)	10 (69)	10-20 (70-138)
SHEAR STRENGTH RÉSISTANCE AU CISAILLEMENT	psi x 10^3 (MPa)				
TENSILE STRENGTH RÉSISTANCE EN TENSION	psi x 10^3 (MPa)	1-3 (7-18)	1-2 (9-12)	1-2 (6-11)	1-2 (9-12)
POINT LOAD STRENGTH INDICE DE DOUBLE POINCONNEMENT	psi x 10^3 (MPa)	9	6	7	6
POISSON'S RATIO RAPPORT DE POISSON		0,23	0,17	0,25	0,17
YOUNG'S MODULUS MODULE DE YOUNG	psi x 10^6 (G Pa)	10 (70)	9 (65)	9 (65)	9 (65)
RQD %		65	61	60	61
GEOMECHANICAL CLASSIFICATION CLASSIFICATION GÉOMÉCANIQUE		9	4	5	1

experience and that therefore the procedure entails little extra expense.

The permeability coefficients of the existing rock have been evaluated based on water pressure tests conducted in the drill holes, the R.Q.D. values and the number of joint sets. The coefficients varied between 10^{-6} cm/s (when the flow was perpendicular to foliation) and 10^{-4} cm/s (when the flow was parallel).

Field tests showed a relationship between the point load strength with NX type boreholes and the uniaxial compressive strength could be established as follows:

$$Is\ (MPa) = 0.043\ Oc\ (MPa)$$

The constants m and s in the equation " $\sigma_1 = \sigma_3 + \sqrt{m\sigma c\sigma_3 + s\sigma^2 c}$ " were based on the properties of the rock. The values m and s are indicated below according to the types of rock (table and scale from Hoek and Brown, 1980, p. 176).

Types of Rock		NGI	m	s
Hanging wall	biotite gneiss	11	2,5	0,004
	quartzite	8	1,4	0,003
	amplibolite	8	2,5	0,004
	skarn	9	1,5	0,004
	skarn leached	0,03	0,007	0
	biotite schist	4	0,5	0,001
Deposit	massive sulfides	5	0,6	0,0001
	breccia sulfides			
Foot wall	biotite schist	1	0,2	0,0001
	quartzite	7	1,3	0,003

3.5 HYDROGEOLOGICAL CONDITIONS

- Overburden

The dredging of sediment at the lake-bottom is presently underway (summer 85); however, the complete drainage schedule has not yet been established.

- Rock Mass

As mentioned in section 3.4, the permeability coefficient varies between 10^{-4} and 10^{-6} cm/s and the flow of water pumped underground reaches 580 (US) GPM (37 L/s). Water and waste water coming from the hydraulic fill is estimated to reach 380 (US)GPM (24 L/s) with extremes climbing to 710 (US)GPM (45 L/s). The principal pumping station is located at the bottom of shaft #1.

3.6 MINING OPERATIONS

. Mining Methods

Presently, Management is employing the following mining methods:

Cut and fill:	60%
Vertical block mining:	30%
Undercut:	10%

The mechanized cut and fill method is used for regular stope exploitation. Pillar recovery is conducted by undercut and fill. The VBM method is currently being tested in several stopes.

. Operating Conditions

Upper stopes have been exploited using the cut and fill method with an extraction percentage of 90 and a dilution percentage of 30. Generally, there is a three month period between the closing of a stope and its refilling.

The stopes are generally mined from bottom, to top and from the center to the extremities, in a longitudinal direction. For the mine as a whole, operations are carried out from top to to bottom. At the time of exploitation of the upper stopes, the floors were not cemented. Now all floors are systematically cemented for cut and fill stopes.

3.7 SUPPORT AND REINFORCEMENT METHODS

. Primary Support

Wall pillars have been left as primary supports and vary in thickness from 80 to 130 ft (24 - 40 m). Their width is equal to that of the orebody.

. Filling and Reinforcement

All upper stopes were filled with cyclone-treated mine tailings (hydraulic fill 50% solid). Wooden towers with jute canvassing have been erected to accelerate stope drainage. The fill material is supported by wooden structures.

Surface pillars have been systematically bolted with standard 6 ft (2 m) long bolts, spaced every 3 - 4 ft (0.9 - 1.2 m). Generally, the bolts are perpendicular to the schistosity or foliation. In the deeper stopes, cables are sometimes installed to support the ceilings.

Torque and traction tests have been conducted on the bolts; however, test results were not available.

3.8 MONITORING PROGRAM(S)

. Stress Measurement

Stress measurements were taken in the rock and fill with the aid of pressure load cells. In certain stopes, "IRAD" horizontal to vertical stress load cells were installed in the fill.

Bi-axial and tri-axial load cells were installed in the rock mass at three different levels in the mine. "In situ" measurements were sometimes distorted by water pressure in the drill hole or by the glue which gave way or would not harden. Eight out of thirteen tests were successful.

As mentioned in section 3.5, the horizontal-vertical stress field ratio equals 4 at level 400 or at the surface pillar base.

Stress field measurements are drawn from three different sources:

1. CSIRO cells
2. USBM cells
3. CANMET measurements

. Displacement Measurement

Vibration cables connected to a digital read-out board provide an indication of displacement in certain lower stopes reputed to be unstable. Direct displacement measurements are occasionally taken between the metallic stems anchored in the walls.

No displacement measurements have been taken in the surface pillar area.

. Other Programs

No specific monitoring program of surface pillars is being applied at the present time.

3.9 SURFACE PILLAR DESIGN

. Personnel Involved

The persons and departments involved in the pillar design are presented in Figure 3.4. The departments of Research, Geology and Mining Engineering are directly involved in the design of the surface pillars. The Assistant Vice-President of the Engineering Division ratifies all decisions ensuing from the three departments.

The Company has initiated and participated in surveys to study the characteristics of the soil and rock masses.

In collaboration with the Company's personnel, advisory experts from an external firm have planned a "step by step" procedure to safely and economically mine the orebody.

. Chronology

The upper stopes (level 400) were mined during the 1960's. Thereafter, an investigatory report concentrating on the upper portion of the mine (i.e. 0 to 1 000 ft (350 m)) evaluated the impact of an eventual open-pit mine on underground operations.

The report also defined a mining sequence for stopes located beneath the 1 000 ft (350 m) level. The details of this survey however, were not available.

ORGANIZATION CHART - PILLARS DESIGN
ORGANIGRAMME - CONCEPTION DES PILIERS

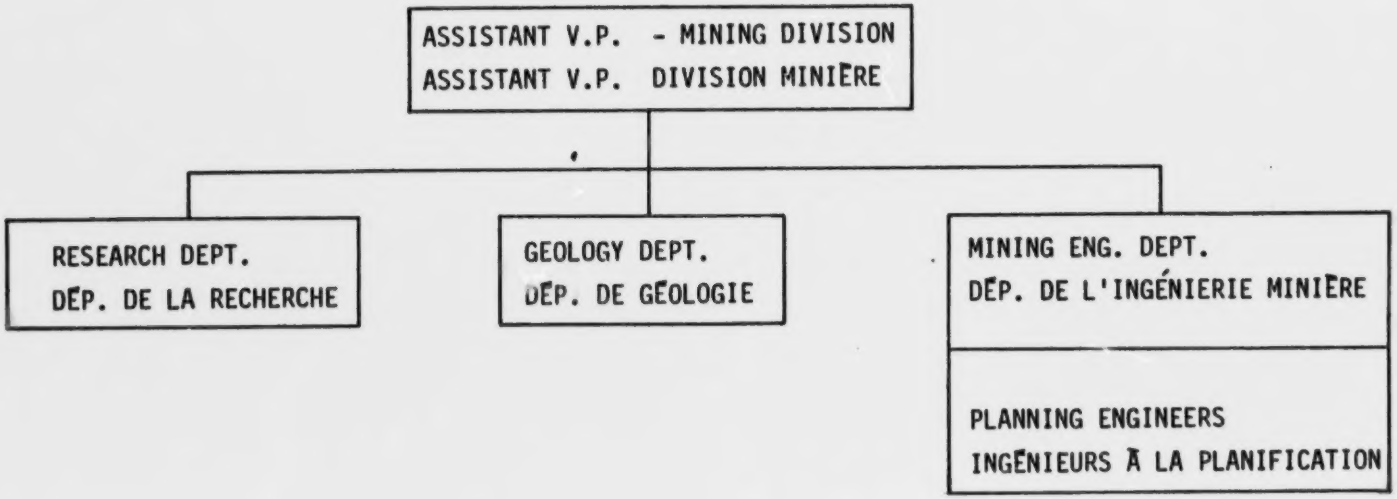
ASSISTANT V.P. - MINING DIVISION
ASSISTANT V.P. DIVISION MINIÈRE
RESEARCH DEPT.
DÉP. DE LA RECHERCHE
GEOLOGY DEPT.
DÉP. DE GÉOLOGIE
MINING ENG. DEPT.
DÉP. DE L'INGÉNIERIE MINIÈRE
PLANNING ENGINEERS
INGÉNIEURS À LA PLANIFICATION

Figure 3.4

According to management, the surface pillars will be exploited by means of an open pit as soon as the overburden has been removed and the last section of ore has been extracted from the underlying underground level.

. Design Factors

Surface pillar design has been based on a conservative approach given the thickness of the lake-covered overburden. An average thickness of 240 ft (73 m) has been decided upon for all the pillars: this figure was based on management's practical experience as well as the dimensions of the upper portion of the orebody.

Since 1965, various rock mechanics tests have been conducted on the principal rock types found in the mine. Since this time, pillar design has relied increasingly on the mechanical properties of the rock and mathematical models simulating prevalent conditions in the mine (geology, hydrogeology, excavation geometry ...).

. Pillar Dimensions

Surface pillar dimensions are indicated in Table 3.4. The thickness/width ratio varies from 1.2 to 8.3.

DIMENSIONS OF SURFACE CROWN PILLARS

DIMENSIONS DES PILIERS DE SURFACE

TABLE 3.4
TABLEAU 3.4

DIMENSIONS		PILLARS - PILIERS							
		#1	#2	#3	#4	#5	#6	#7	#8
. THICKNESS: EPAISSEUR:									
- WATER BODY PLANS D'EAU	feet-pi. (m)	10 (3)	10 (3)	10 (3)	10 (3)	10 (3)	10 (3)	10 (3)	
- OVERBURDEN MORTS-TERRAINS	feet-pi. (m)	60 (18)	70 (21)	90 (27)	110 (33)	60 (18)	90 (27)	70 (21)	
. SURFACE CROWN PILLAR: PILIER DE SURFACE:									
- THICKNESS EPAISSEUR	feet-pi. (m)	230 (70)	220 (67)	250 (76)	200 (61)	260 (79)	240 (73)	260 (79)	
- WIDTH LARGEUR	feet-pi. (m)	70 (21)	70 (21)	30 (9)	90 (27)	140 (43)	200 (61)	70 (21)	
- LENGTH LONGUEUR	feet-pi. (m)	780 (238)	900 (274)	800 (244)	1200 (366)	300 (91)	420 (128)	450 (137)	
- THICKNESS/WIDTH RATIO RAPPORT EPAISSEUR/LARGEUR		3.3	3.1	8.3	2.2	1.9	1.2	3.7	
. STOPE HEIGHT HAUTEUR DU CHANTIER	feet-pi. (m)	600 (183)	600 (183)	600 (183)	600 (183)	600 (183)	600 (183)	600 (183)	
. FILL HEIGHT (EST) HAUTEUR DU REMBLAI	feet-pi. (m)	600 (183)	600 (183)	600 (183)	600 (183)	600 (183)	600 (183)	600 (183)	

3.10 VISUAL EVALUATION OF SURFACE PILLAR(S)

The visual inspection has been limited to drifts bordering the filled stopes on the footwall side. The walls are generally massive and practically dry. On occasion, several humid areas can be observed which do not, however, indicate the presence of a continual or drip flow. No major faults or shearing zones have been observed. R.Q.D. values are estimated at approximately 70%.

Along one drift crossing the longitudinal axis of the surface pillars, there are wooden retention walls containing fill consisting of mine tailings. Wooden scaffolding wrapped in jute has been built to accelerate the draining of the fill.

3.11 MANAGEMENT'S COMMENTS

Management mentions that the mining of surface pillars can be carried out in either of two ways:

- Leaving one more layer of ore than is necessary above the upper stopes, the mine can then be exploited after which the ore can be extracted from the surface pillars (adopted solution);
- Thoroughly excavating surface pillars from the beginning or during exploitation of the deposit while honouring minimal dimensions required to ensure the stability and safety of underlying stopes.

In general, drillings do not provide sufficient information to develop surface pillar design: practical experience must complete the pillar design and should include the following phases:

- Collection of data
- Geomechanical modeling
- Comprehensive analysis
- Supervisory program during mining

MINE #4

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4.0 SUMMARY OF THE VISIT

The surface pillars cover five (5) partially filled stopes. The deposit is composed of massive sulfides rich in zinc. The upper part of the deposit consists of a vein which reaches the rock surface and which strikes N23° W at a dip of 45° NE.

The conditions of the terrain above the deposit were modified over the years in the following manner.

Initial conditions: lake on the surface and glacial soil.

Present conditions: after digging a diversion canal, the lake slowly became swampy. Glacial soils will eventually be removed to allow open pit mining of the surface pillars.

The thickness of the surface pillars varies greatly from one stope to another: 80 ft (24 m) for stope no.1, situated at the most westerly point and 160 ft (49 m) at the most easterly stope (no 5). The size of the surface pillars is based on management's practical experience. Originally, management chose an arbitrary thickness of 120 ft (37 m), ie. about twice as large as the upper stopes. This thickness was modified based on the grade of ore and the position of the rock interface as revealed over the course of operations.

4.1 GENERAL INFORMATION

. Regional Geology

The mine is situated in a series of volcanic rhyolitic rocks containing an ore strip of sphalerite that subdivides into several lenses at a greater depth. The walls are characterised by metamorphized tuffs in schists of sericite and chorite, and gneiss of quartz and biotite. Further from the deposit, one finds gabbro and andesite in the lower and upper walls respectively (see figures 4.1 and 4.2).

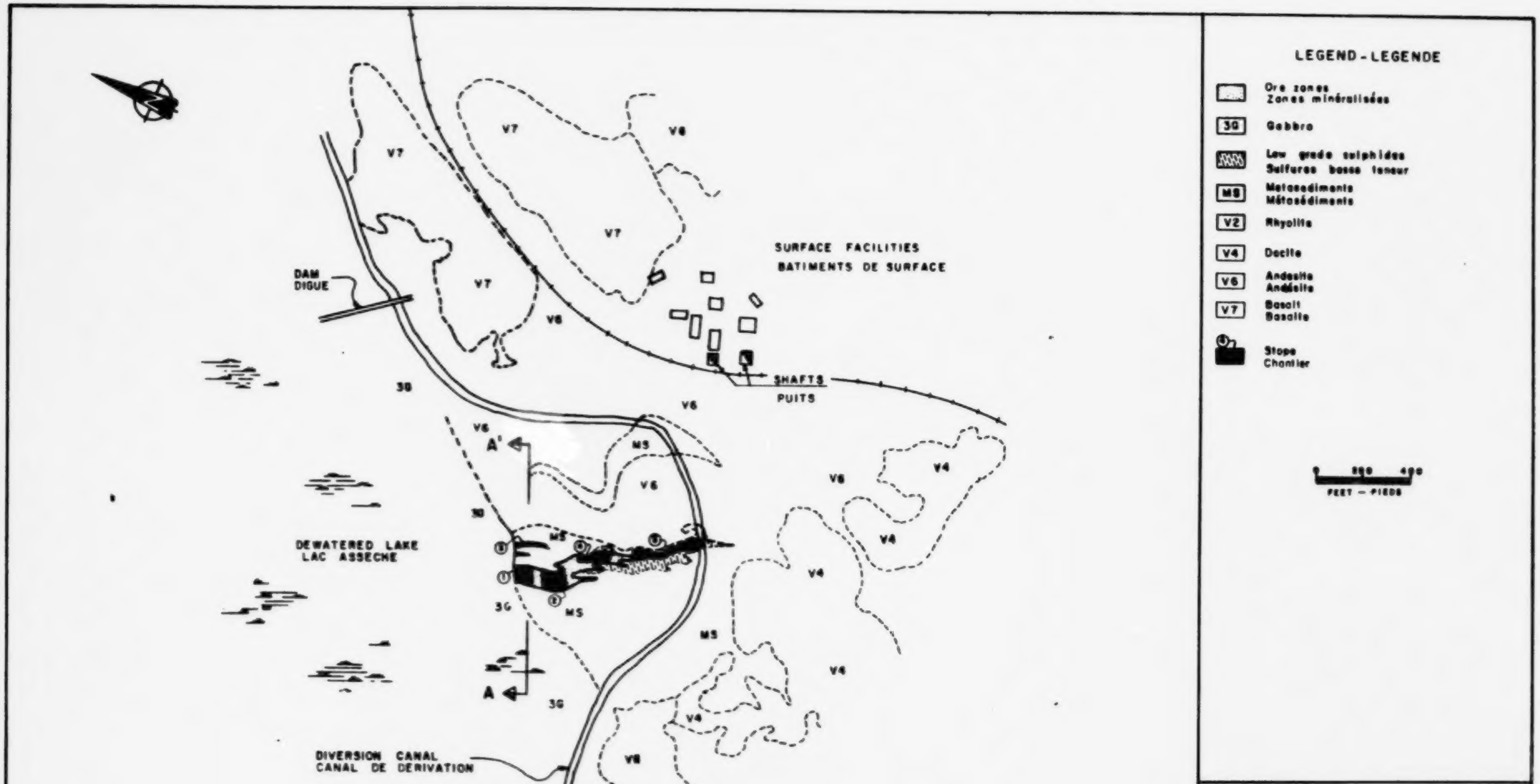
. Characteristics of the Deposit

The ore is composed of sulfides rich in zinc with some copper, silver, gold and lead.

The deposit is of the metavolcanic type and composed of stratified strips.

Close to the surface, the deposit is composed principally of a massive zone of sphalerite, pyrite, pyrrhotite, chalcopyrite, carbonate and a gangue in the form of chlorite and sericite schists. From the surface to a depth of 600 ft (183 m), this massive ore zone extends along an 800 ft (244 m) length with a width of 60 ft (18 m). The average dip of this part of the deposit is 45°NE in a N 23°W direction.

At the deepest point, the deposit divides into several zones oriented differently. These zones can reach depths of over 1 400 ft (427 m).


LEGEND - LEGENDE
Ore zones
Zones minéralisées
3G Gabbro
Low grade sulphides
Sulfures basse teneur
MS Métasédiments
Métasédiments
V2 Rhyolite
V4 Dacite
V6 Andesite
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ROCHE

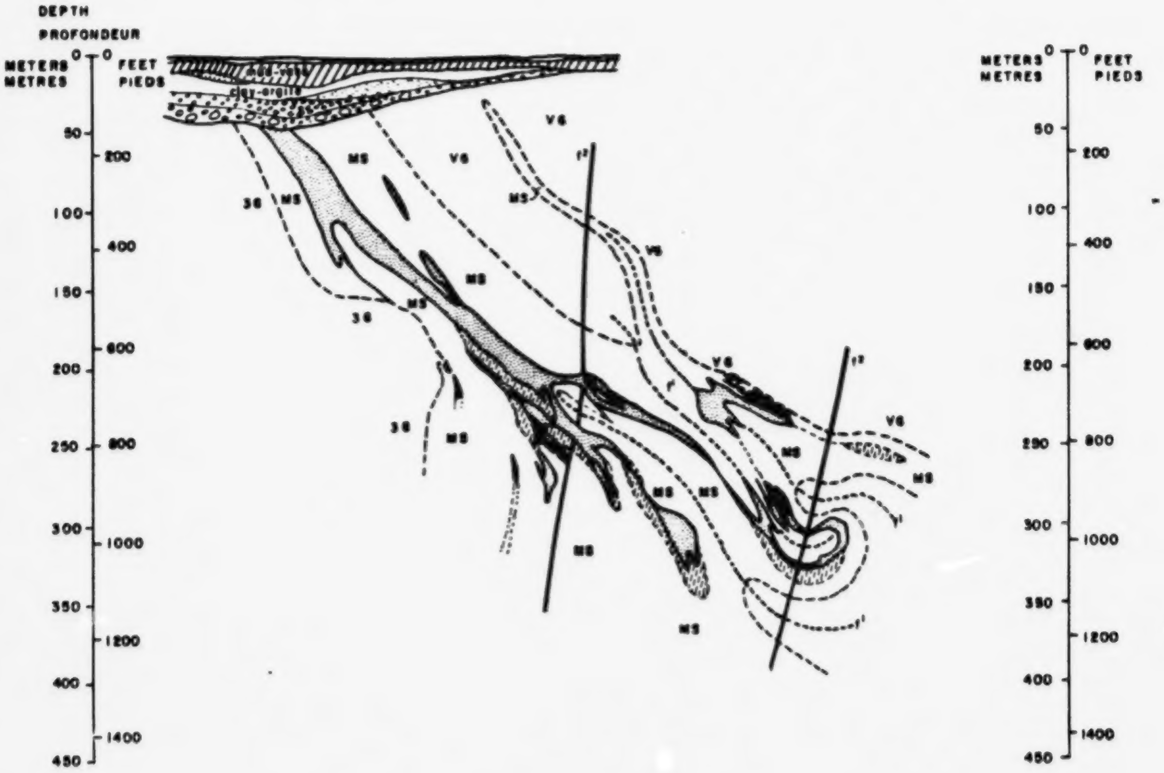
Sainte-Foy Québec

[illegible] Canada

MINE #4 MINE

SURFACE PLAN
PLAN DE SURFACE

Date	Figure
06/85	4.1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LEGEND - LEGENDE

▒	Ore zones Zones minéralisées
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▨	Low grade sulphides Sulfures basse teneur
■	Tremolite carbonate rocks Roches carbonatées et trémolite
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V6	Andesite Andésite
———	2nd Folds f² trace of axial plane 2ème Phase f² de plissement
----	1st Folds f¹ trace of axial plane 1ère Phase f¹ de plissement

SECTION
COUPE A-A'

ROCHE
associés ltée
Groupe conseil

2535, boul Laurier
Sainte Foy, Québec
G1V 4M3 Canada
(418) 871 [illegible]
Télex [illegible]

MINE #4 MINE

GEOLOGICAL SECTION
COUPE GEOLOGIQUE

Date 06/85

Figure 4.2

This mine produces 800 tons daily and is operated on a continual basis.

4.2 MINE ENVIRONMENT

The surface pillars are situated below a lake that has now been dewatered. No instrumentation monitoring program has been installed on the surface. No visual indications of compression, however, have been noted.

A diversion canal was dug in order to dewater the lake, and two dams are presently under construction in order to contain the water outside the zone overhanging the surface pillars. The objective of these works is to exploit the surface pillars by developing an open pit mine. (see Figure 4.1)

An active underground mine is situated approximately 2 000 ft (610 m) to the east. No special measures have been implemented given the large distance between this latter mine and the one presently under study.

4.3 OVERBURDEN

. Studies

The exploitation of the surface pillars has been anticipated for over thirty (30) years. A number of studies, conducted by the company's personnel and by external consultants, indicate the main steps to be taken in order to dewater the lake and the terrain above the surface pillars. During the 50's, close to 10 000 ft (3 000 m) of drilling allowed the company to determine the soil stratigraphy and the topography of the bedrock. The drill hole pattern was 150 ft by 150 ft (46m by 46m). The data from these drillings have been instrumental in the establishment of the volume of ground to excavate before exploiting the surface pillars by open pit. Some drill holes from the drifts and underground stopes have permitted determination of the precise location of the soil-rock interface.

The dips indicated in the terrain surrounding the eventual open pit mine are as follows:

Year of the Study Type of Soil	1957 Slope	1980 Slope
Sand + Gravel + Boulders	1 : 2	
Sand + Clay	1 : 2	
Clay	1 : 6	1 : 5
Clay + Silt (Mud)	1 : 20	
Silt		1 : 2.7
Silt + Sand		1 : 1.75

The safety factors used in the stability studies vary between 1.4 (wedge slide) and 2.3 (circular slide). The minimum overall soil security factor was 1.81; in clay it was 2.1, in silt of 1.3 and in the silts, sand and gravel of 1.45.

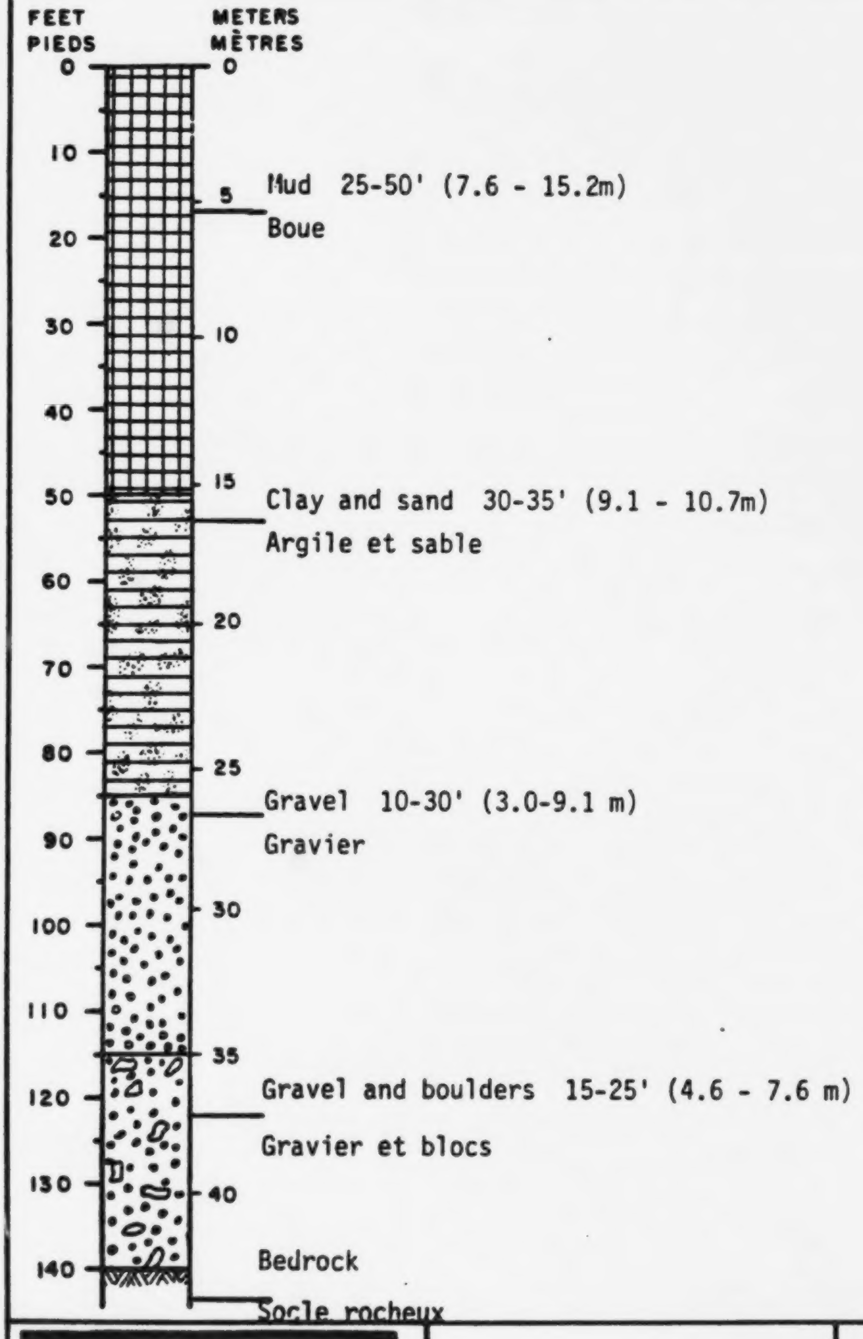
. Stratigraphy and Characteristics

Figure 4.3 gives an overview of the soil covering the surface pillars. Clay samples taken from the mining site are inorganic and have a high level of plasticity. Table 4.1 gives the results of tests conducted on samples taken during the sinking of two shafts in the soils above the mine. The two shafts reach depths of 91 and 127 ft (28 and 39m) and attempts at pumping were not successful due to technical difficulties.

The nature of the surface terrain has changed since the 50's when the lake was partially dewatered. Today a marshy zone can be observed and, in places, there are clumps of young trees along the original shoreline.

The management of the mine does not beleive that an erosion canal crossing the soils to the rock overhanging the upper underground stopes might form.

SOIL STRATIGRAPHY
STRATIGRAPHIE DU SOL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35
40
Mud 25-50' (7.6 - 15.2m)
Boue
Clay and sand 30-35' (9.1 - 10.7m)
Argile et sable
Gravel 10-30' (3.0-9.1 m)
Gravier
Gravel and boulders 15-25' (4.6 - 7.6 m)
Gravier et blocs
Bedrock
Socle rocheux

ROCHE associés ltée Groupe-conseil 2535, boul Laurier, Sainte-Foy, Quebec G1V 4M3 Canada (418) 871 9800 Télex QBC 051 31593	MINE # 4 MINE	Date 07-1985	Figure 4.3

SOILS CHARACTERISTICS

CARACTÉRISTIQUES DES SOLS

TABLE: 4.1
TABLEAU: 4.1

PARAMETERS PARAMÈTRES	CLAY ARGILE	SILT SILT	SAND & SILT SABLE & SILT	GRAVEL GRAVIER	
UNIT WEIGHT lb/ft^3 POIDS VOLUMIQUE (kN/m^3)	102 (16)	124 (19)	124 (19)	124 (19)	
LIQUID LIMIT % LIMITE DE LIQUIDITÉ	55-85	27	-	-	
PLASTIC·LIMIT LIMITE DE PLASTICITÉ %	7-28	-	-	-	
WATER CONTENT % TENEUR EN EAU	56-59	21-33	-	-	
APPARENT COHESION lb/ft^2 COHÉSION APPARENTE (kN/m^2)	500 (24)	10000(1) (479)	-	-	
EFFECTIVE COHESION lb/ft^2 COHÉSION EFFECTIVE (kN/m^2)	8 (0,4)	0-1775 (0-85)	-	-	
APPARENT ANGLE OF FRICTION ANGLE DE FROTTEMENT APPARENT	-	35°(2)	45°		
SPT BLOW COUNT NOMBRE DE COUPS SPT	-	6-15	5-60	30-68	
COEFFICIENT OF PERMEABILITY COEFFICIENT DE PERMÉABILITÉ x 10^{-7}cm/s	4,5-7,8	3-50	-	-	

(1) Undrained - non drainé
(2) Drained - drainé

4.4 ROCK MASS

. Nature of the Rock

The nature of the rock mass is as follows;

footwall :	metasediments, chlorite gneiss, chlorite and gabbro schist
deposit :	sulfides with a carbonate gangue
hanging wall:	sericite quartz, biotite and andesite gneiss.

The deposit is bordered by a zone of silicification, chloritization and sericitization which extends for over 1 000 ft (305m) along the ore. The walls are characterized by layers of carbonates and amphibolites several centimeters thick. The host rock is also characterized by schists, and gneiss of biotite, staurolite and garnets. The ore zone is located in metamorphic facies of green schist.

. Structural Geology

The structural geology of the deposit is made complex by the action of two phases of folding and at least three families of major faults. The folding of the first phase follows the dip of the deposit, whereas those associated with the second phase are subvertical (see Figure 4.2) The three families of major faults are as follows:

	Strike	Dip
1st family	E - W	30°N
2nd family	N47°E	40-60°NW
3rd family	N47°E	50°NW

These faults segment the deposit and, with the folding phases, cause the system of joints to be irregular. The fill material in the faults is composed of mylonite, clay, sericite and sulfides. These weak planes generally contain very little water.

The joints are discontinous and have irregular dips and strikes. The spacing of the joints is a few millimeters thick. The fill material is composed of quartz and/or carbonate. Approximately 95% of the joints are dry while the remmaining 5% drip slightly. The surface of the joints is generally smooth.

No statistical study has been carried out on the joints. The mapping of the levels, however, shows that lineations are for the most part parallel to the axes of the folds. The schistosity and bedding often change direction in the upper levels. Tests of the terrain conducted in the area have shown that residual horizontal stress nearly doubles vertical stress.

The contacts between the deposit and the host rock are distinct. Sometimes they are discordant and show an interdigitate motif.

. Characteristics

There has been no testing or calculation of the geomechanical properties of the mine. The rock quality designation (R.Q.D.) and geomechanical classifications have not been used as working tools. Knowledge of the rock mass resides mainly on structural geology and on a visual evaluation of the behaviour of the rock. The average density of the rock walls and of the deposit is 2.77 and 4.04 respectively.

4.5 HYDROGEOLOGICAL CONDITIONS

. Overburden

Above the surface pillar, there is a lake partially dewatered by a canal built during the 50's. The water from this lake continues to flow out slowly through a diversion canal. As mentioned in chapter 4.2, two dams will be built in order to prevent the water from flowing onto the operations site. Permeable horizons have been identified on the terrain. No average value of the permeability coefficient has been obtained given the difficulties mentioned in chapter 4.3.

The operations of the upper part of the deposit have been the object of numerous internal studies.

. Rock Mass

No hydrogeological study has been conducted on the rock mass. To dewater the mine, three sumps, dug at three different levels, collect the water which is pumped up to the surface in steps. The average pumping rate at the exit of the mine is 74 (US)GPM (4.6 L/s).

In 1980, holes were drilled into the surface pillars in order to better identify the ore. These holes were subsequently injected with cement to contain the surface water.

In spite of the swamps on the surface, little water seeps into the mine (74 (US)GPM); layers of fine soil composed of clay and clay-silt act as a protective screen.

4.6 MINING OPERATIONS

. Mining Methods

The upper stopes have been exploited using the longhole blasting method. The stopes were mined from sublevels through ring-drilled vertical trenches. At a depth of 1 050 ft (325 m), the deposit was mined according to the cut-and-fill method.

. Operating Conditions

The recovery of reserves in the upper stopes is approximately 70% and the dilution is 20%. Mining is generally carried out from the upper to the lower levels of the deposit.

Blasting parameters are as follows:

Powder factor	1-1.2 lbs/t (2 000 lbs) 0.4-0.5 kg/t
Diameter of holes	2 po (5 cm)
Length of holes	60 ft (18 m)
Spacing (max.)	8 ft (2.4 m)
Burden	4 ft (1.2 m)

4.7 SUPPORT AND REINFORCEMENT METHODS

. Primary Support

For more than fifteen (15) years, the upper stopes located immediately under the surface pillars have been without support, with the exception of two (2) of the largest stopes which are separated by an ore pillar, 35 by 80 ft (11 by 24 m). This latter stope will eventually be exploited.

. Filling and Reinforcement

The upper stope has not been systematically bolted. In the lower stopes, standard bolts, 5 to 6 ft (1.5 to 1.8 m), are used to solidify the walls. "Swellex" bolts are sometimes used to reinforce the drawing points where the rock is more schistic. Resinous bolts are seldom used except where fracturing is high. The percentage use of each of the standard, "swellex" and resinous bolts is 95%, 4% and 1% respectively.

Grouted cables are used in the lower stopes. Therefore, in order to exploit the ore zones located between the two stopes, already exploited and filled with slag, 5/8 inch (1.6 cm) cables were inserted and grouted into a network of vertically drilled holes, 50 ft (15 m) in length and layed out according to a pattern measuring 10 by 10 ft (3 by 3 m).

Steel mesh is used occasionally in stopes where the ceiling is highly fractured. Wooden supports are practically non-existent; however, at the 1 450 level, a drift was timbered along a length of approximately 40 ft (12 m).

The upper stopes are empty or partially filled with coarse slag. Stopes situated at the 850 level and deeper are filled with classified mine tailings. The speed of the water passing through the fill is about 3½ inches (8.9 cm) per hour and its granulometry is as follows;

# "mesh"	% weight
48	2.54
65	4.27
100	10.89
150	15.83
200	20.32
325	23.38
> 325	22.77

4.8 MONITORING PROGRAMS

. Stress Measurement

No measurement of stress has been taken in the underground openings.

. Displacement Measurement

No measurement of displacement has been taken.

. Other Programs

A monitoring program to verify the water level has been in place for approximately eight (8) years. The water level is measured monthly on the surface of the marsh and in several piezometers dispersed in the terrain overhanging the surface pillars.

Each month a visual inspection of the upper stopes is carried out, however, no written report is submitted with the inspection.

Management believes that the surface pillars are secure; thus, there is no immediate need for a monitoring program based on stress/deformations.

4.9 SURFACE PILLAR DESIGN

. Personnel Involved

The Chief Engineer of the Mine Engineering Department is responsible for the design of the surface pillars. This person is charged with examining the solutions proposed by the Engineers in Planning. Then, the solutions are discussed with Geologists and the Chief Engineer of the mine as a whole. Once a solution has been adopted, it is submitted to the mine's Director for final approval. Figure 4.4 gives an overview of the various persons involved in the pillar design.

The mine's management follows no strict method for changing its choice of pillar design. The decison-making process is based on experience and prudence.

The Company has not conducted any particular study of the surface pillars except for establishing the nature of the soil-rock interface through a drilling program. From this program it was possible to establish a detailed stratigraphy of the soil above the deposit.

External consultants studied various methods of dewatering the lake above the surface pillars as well as methods of exploiting the upper part of the deposit by open pit.

ORGANIZATION CHART - PILLARS DESIGN
ORGANIGRAMME - CONCEPTION DES PILIERS

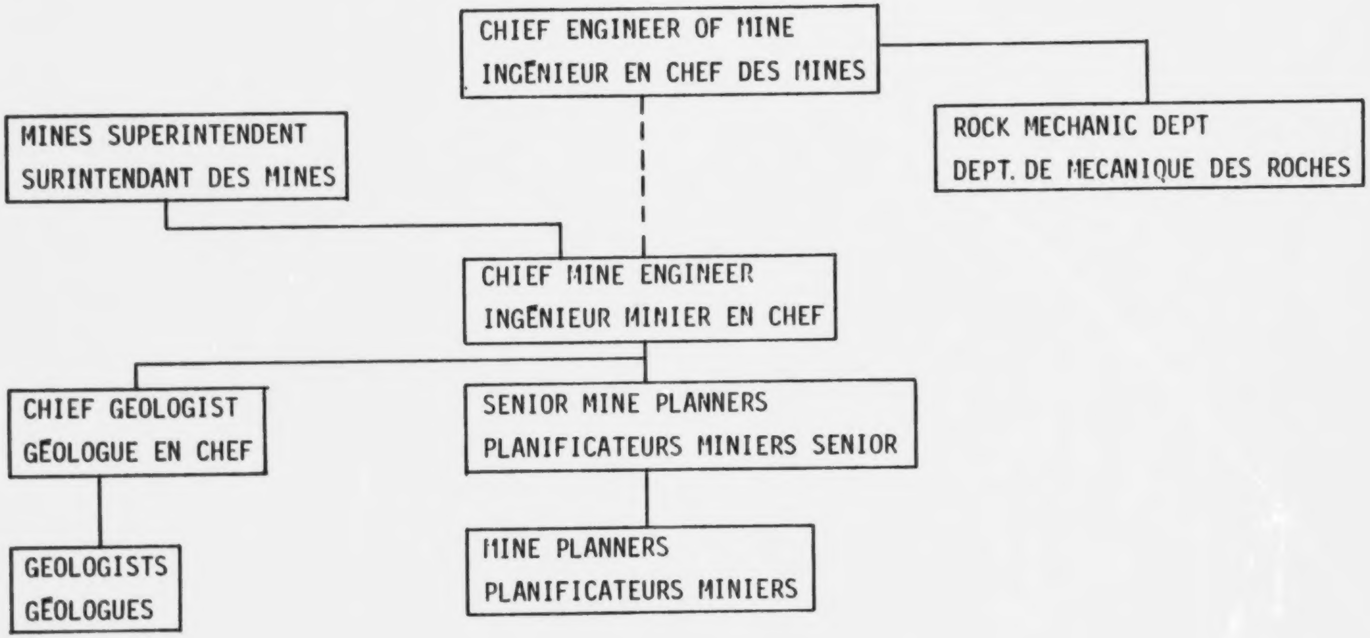
CHIEF ENGINEER OF MINE
INGÉNIEUR EN CHEF DES MINES
ROCK MECHANIC DEPT
DEPT. DE MECANIQUE DES ROCHES
MINES SUPERINTENDENT
SURINTENDANT DES MINES
CHIEF MINE ENGINEER
INGÉNIEUR MINIER EN CHEF
CHIEF GEOLOGIST
GÉOLOGUE EN CHEF
SENIOR MINE PLANNERS
PLANIFICATEURS MINIERS SENIOR
GEOLOGISTS
GÉOLOGUES
MINE PLANNERS
PLANIFICATEURS MINIERS

Figure 4.4

. Chronology

The plan to exploit the upper part of the deposit can be broken down into three (3) steps;

i) exploitation by the longhole method and open stopes from the 250 level to approximately 120 ft (37m) above the bedrock.

ii) open pit mining of the surface pillars.

iii) final phase of recuperation from the surface pillars between the 450 and 250 levels.

. Design Factors

The temporary preservation of the surface pillars depends particularly on hydrogeological conditions. As soon as the upper part is dewatered, management will undertake operations. Preparatory studies have mainly been oriented towards soil analysis.

The preliminary design procedure was based solely on the experience of persons involved in similar projects and on data collected in similar projects. At the beginning of mining operations, the thickness of the surface pillars was set arbitrarily at approximately 120 ft (37m) without having recourse to the approach based on theoretical models.

. Pillar Dimensions

The present thickness of the surface pillars is very much a function of the grade of zinc encountered in the stopes (see Table 4.2).

DIMENSIONS OF SURFACE CROWN PILLARS

DIMENSIONS DES PILIERS DE SURFACE

TABLE 4.2
TABLEAU 4.2

DIMENSIONS		PILLARS - PILIERS							
		# 1	# 2	# 3	# 4	# 5			
. THICKNESS: EPAISSEUR:									
- WATER BODY PLANS D'EAU	feet-pi. (m)	*	*	*	*	*			
- OVERBURDEN MORTS-TERRAINS	feet-pi. (m)	140 (43)	140 (43)	140 (43)	110 (34)	60 (18)			
. SURFACE CROWN PILLAR: PILIER DE SURFACE:									
- THICKNESS EPAISSEUR	feet-pi. (m)	80 (24)	100 (30)	120 (37)	150 (46)	160 (49)			
- WIDTH LARGEUR	feet-pi. (m)	40 (12)	90 (27)	40 (12)	30 (9)	35 (11)			
- LENGTH LONGUEUR	feet-pi. (m)	130 (40)	190 (27)	150 (46)	135 (41)	260 (79)			
- THICKNESS/WIDTH RATIO RAPPORT EPAISSEUR/LARGEUR		2,0	1,1	3,0	5,0	4,6			
. STOPE HEIGHT HAUTEUR DU CHANTIER	feet-pi. (m)	180 (55)	140 (43)	200 (61)	260 (79)	200 (61)			
. FILL HEIGHT HAUTEUR DU REMBLAI	feet-pi. (m)	100 (30)	100 (30)	160 (49)	220 (67)	170 (52)			

* swamps - marécages

4.10 VISUAL EVALUATION OF THE SURFACE PILLAR(S)

Visual inspection covers the five (5) upper stopes (see Figure 4.1) accessible at the 250 level. The inspection, however, is limited to the accesses of the stopes, particularly those that have been partially filled.

The stopes and access drifts are mostly made up of massive rock that is competent where the fractures are discontinuous and irregularly spaced. In places, three families of joints that segment the parallelepiped blocks can be distinguished. For the most part, these joints are dry except for 20% which have a humid surface or slight dripping. The strike and dip of the joints vary greatly from one place to another.

A summary visual estimation of the rock walls sets their R.Q.D. value between 70 and 80%.

The walls show no sign of distorsion or displacement. The drill holes passing through these rocks have remained round and do not seem to show deformations in the visible section. Few bolts have been installed in the drifts and stopes.

A limited amount of water is found in the stopes and drifts. Drill holes which have served to evaluate the grade of the surface pillar do not seem to have been grouted afterward. Small streams of water pass through these drill holes carrying with them fine particles probably from the soil above the surface pillars. There are clay-silt deposits at the base of the holes.

Stopes #1 and #2 contain only a small amount of slag. The floors of the stopes are approximately 100 ft (30 m) from the ceiling. The footwalls of these stopes are marked by schistosity that are well developed and strike along the deposit.

Near the entrance of stope #3, the footwall has a fault subparallel to the deposit. The fractures contain one (1) or two (2) inches of clay and schistic material. The hanging wall is situated about 40 ft (12m) above the slag.

The roof of stope #4 is more fractured than the others and the rock walls were more humid. The beginings of a chimney has already formed close to the north entrance of the stope. Steel mesh was fixed to the ceiling by a single bolt. The roof of the stope is situated about 40 ft (12m) above the slag.

Stope #5 seems slightly more filled than the others; there is approximately 30 ft (9 m) between the hanging wall and the slag fill. The dip of the footwall is more acute than the average deposit, approximately 60° instead of 45°.

The conditions of the terrain above the surface pillar can be described as marshy dotted by small islands covered by vegetation; the terrain sits on granular deposits.

4.11 MANAGEMENT'S COMMENTS

According to Management, one of the first steps towards pillar design is the preparation of geological cross-sections illustrating the rock mass in detail. In addition, the types of soil above the orebody and the level of soil-rock contact must be verified.

Over the course of the development works, particular attention must be paid to the following conditions:

- sloughing or scaling of the walls;
- falling rock;
- structural geology

Research orientations in this area must be based particularly on the geometric relationships of the surface pillars and their dimensions should be compiled in a publicly accessible data base.

MINE #5

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5.0 SUMMARY OF THE VISIT

The mine is composed of metavolcanic deposits mineralized into copper, zinc, silver and gold. The exploited portion is in tabular form dipping at 70-75°E.

A lake situated about 200 ft (60 m) from the upper stope and an aquifer horizon linking the stope to the lake caused the mine's management to delay exploitation of the upper part of the deposit.

Located beneath a 14 ft (4.3 m) thick layer of overburden, two sedimentary rock formations lie in discordance on the Precambrian rocks:

- limestone dolomite, very fractured and permeable (26 ft: 8 m)
- basal sandstone, very permeable (7 ft: 2 m)

The exploitation of the upper stope had to be interrupted because of the extent of fracturing in the walls. The shrinkage stoping method was used in this stope; however, for all other stopes, the VCR method was used.

The surface pillar was originally designed to permanently protect the stopes. However, over the last few years, management has been studying the possibility of working the upper portion of the deposit.

The following problems must be faced in order to partially or totally exploit the surface pillar: the high degree of fracturing of the walls at level 45, low competence and the permeability of the Ordovician sedimentary rocks overlying the deposit.

The sizing of the pillar was based on practical experience and on data gathered during exploration and development. The pillar has an average thickness of 246 ft (75 m) including the Ordovician rock.

5.1 GENERAL INFORMATION

. Regional Geology

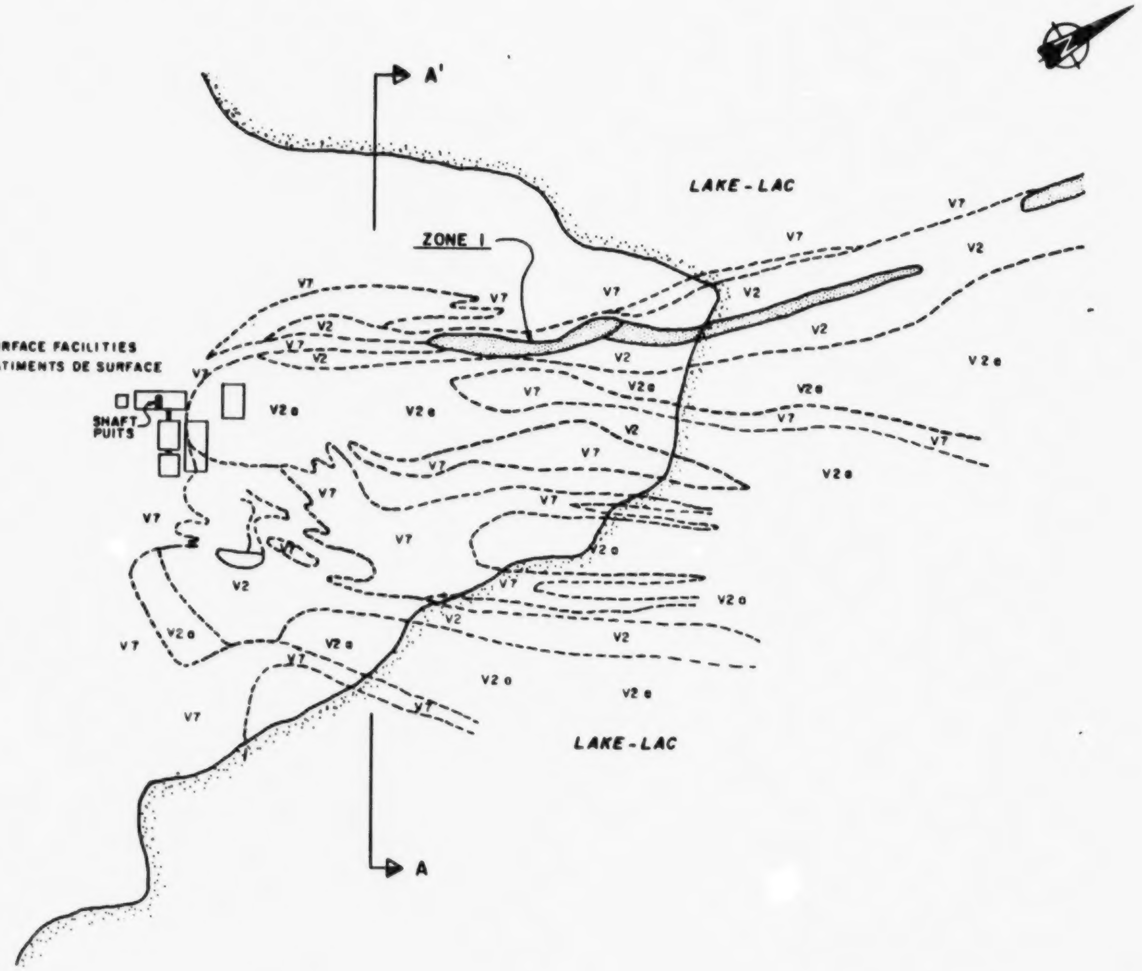
The mining property is located in the geological province of Churchill. The region is characterized by gabbro intrusions, granite gneiss, granite, metasediment and volcanic rocks. These Precambrian rocks show a metamorphic facies of the amphibolite type. Ordovician sedimentary rocks lie in discordance over the Precambrian rock.

. Local Geology

The mine is located in a collection of volcanic rocks composed mainly of fragmented rhyolite (sometimes silicified), basalt, dacite and andesite. These bands of rock are tightly folded and the axis of the folds runs N-S or NNE-SSW (see figures 5.1 and 5.2).

. Characteristics of the Deposit

The mine is made up of metavolcanic deposits mineralized into copper, zinc, silver and gold. The mine is subdivided into four (4) zones striking approximately NS. Only zone #1, nearest the surface, will be considered in this study; in tabular form, this zone dips 70-75°E with a slope of 40-50°S.


A'
LAKE-LAC
ZONE I
SURFACE FACILITIES
BATIMENTS DE SURFACE
SHAFT
PUITS
V7
V2
V2a
LAKE-LAC
A

LEGEND - LEGENDE

▭	Ore Zones Zones minéralisées
V7	Basalt
V2	Fragmented rhyolite Rhyolite fragmentée
V2a	Fragmented silicified rhyolite Rhyolite silicifiée fragmentée

0 100 200
FEET - PIEDS

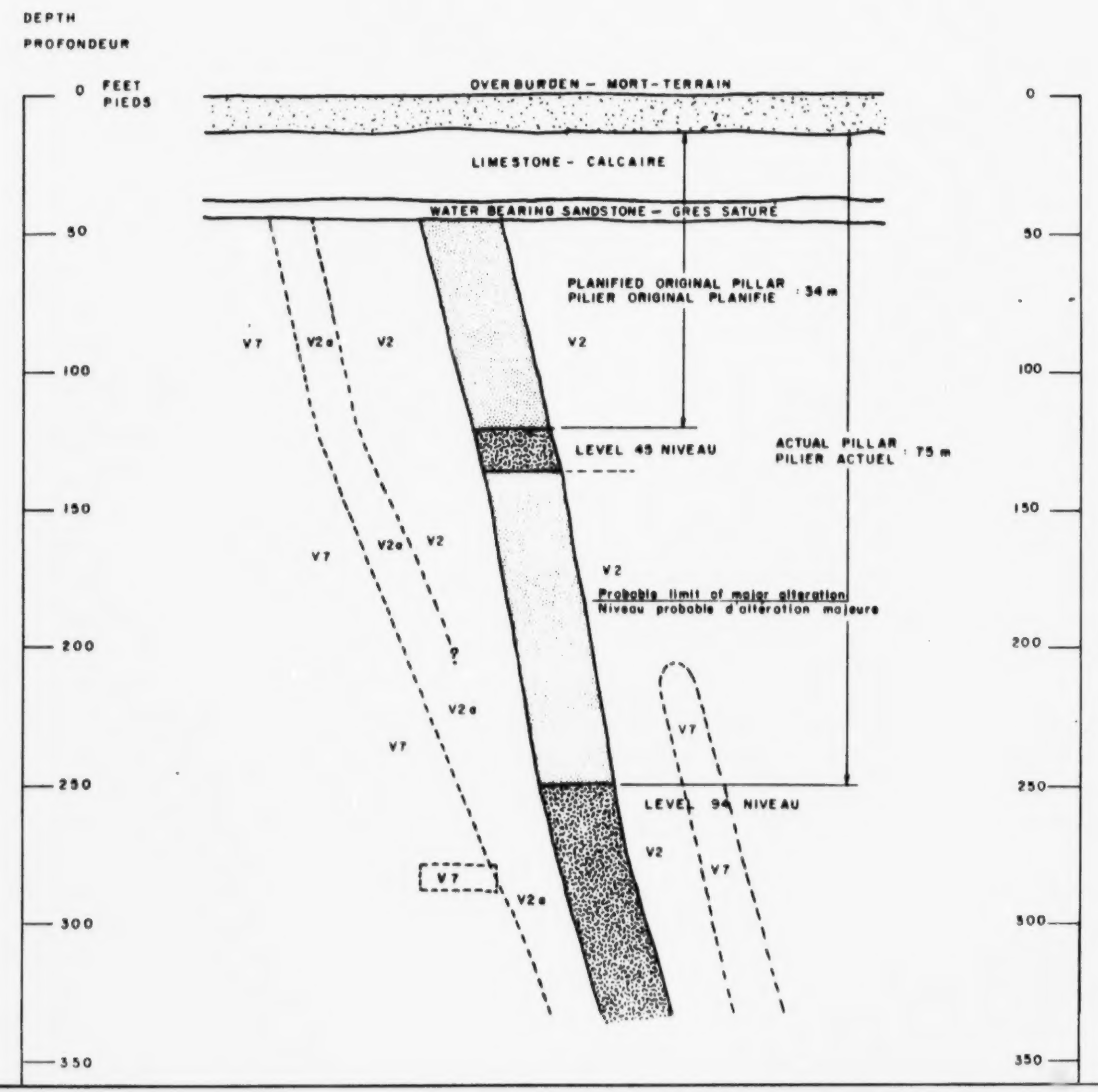
ROCHE
associés ltée
Groupe conseil

[illegible]
Sainte-Foy Québec
[illegible] Canada
[illegible]
[illegible]

MINE # 5 MINE

SURFACE PLAN
PLAN DE SURFACE

Date 06/85
Figure 5.1


DEPTH
PROFONDEUR
FEET
PIEDS
0
50
100
150
200
250
300
350
OVERBURDEN – MORT-TERRAIN
LIMESTONE – CALCAIRE
WATER BEARING SANDSTONE – GRES SATURE
PLANIFIED ORIGINAL PILLAR
PILIER ORIGINAL PLANIFIE : 34 m
ACTUAL PILLAR
PILIER ACTUEL : 75 m
LEVEL 45 NIVEAU
LEVEL 94 NIVEAU
Probable limit of major alteration
Niveau probable d'alteration majeure
V7
V2a
V2
?
0
20
40
FEET - PIEDS

LEGEND - LEGENDE

- ▒ Ore zones / Zones minéralisées
- V7 Basalt
- V2 Fragmented rhyolite kaolinized / Rhyolite fragmentée kaolinisée
- V2 a Fragmented silicified rhyolite / Rhyolite silicifiée fragmentée
- ▩ Stope / Chantier

SECTION
COUPE A-A'

ROCHE

MINE # 5 MINE

GEOLOGICAL SECTION
COUPE GEOLOGIQUE

Date	Figure
06/85	5.2

The dimensions of zone#1 are as follows:

Length	Width	Depth
355 ft	20-45 ft	1880 ft
(108 m)	(6-14m)	(573 m)

The presence of a nearby lake and aquiferous formations linking the mine to this lake complicate eventual exploitation of the surface pillar. Also, Ordovician formations, spread disconcordantly over the host rock, seem to have unpredictable geomechanical behaviour patterns.

5.2 MINING ENVIRONMENT

No infrastructure is situated over the surface pillar and no other mine is present in the vicinity. A lake is situated at about 200 ft (60 m) from the surface pillar area and the pillar is covered with soil. The level of the lake varies slightly between 915 and 916 ft (278.9 and 279.2 m) while the level of the soil over the deposit varies between 920 and 925 ft (280-282 m). The level of the neck of the shaft is 927 ft (282.5 m).

5.3 OVERBURDEN

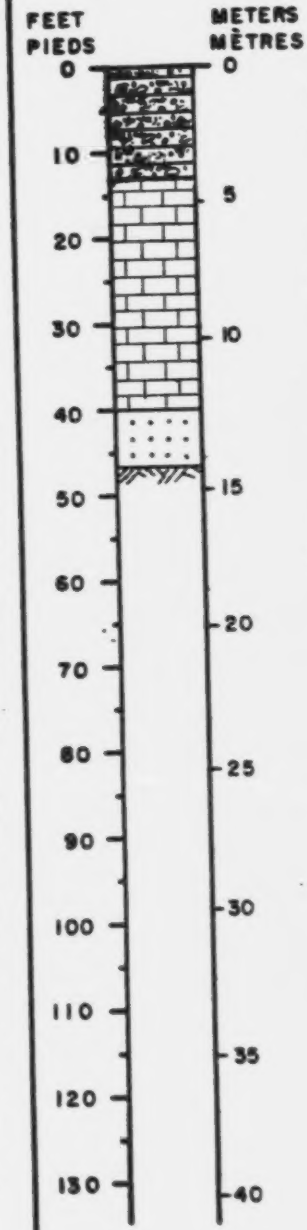
. Studies

No geotechnical study has been carried out on this property. However, data gathered during exploration have been used to determine soil stratigraphy. The work of boring the shaft and a ventilation raise also helped identify the soils.

. Stratigraphy and Characteristics

The soil is composed of a layer of organic matter and of a mixture of gravel, sand, boulders and clay (Figure 5.3) with a total thickness of 14 ft (4.3 m). Below these soils are two formations of sedimentary rocks; at the overburden interface there is dolomitic limestone 26 ft (8m) thick and below that, permeable basal sandstone 7 ft (2.1 m) thick. Mine management mentions that these two rock formations are of low competence and as a result are considered as part of the overburden for any stability study of the stopes, drifts, etc. of the upper part of the mine.

SOIL STRATIGRAPHY
STRATIGRAPHIE DU SOL


FEET
PIEDS
METERS
MÈTRES
0
10
20
30
40
50
60
70
80
90
100
110
120
130
0
5
10
15
20
25
30
35
40

Organic layer, gravel, sand, boulders and clay 14 ft (4.3m)
Horizon organique, gravier, sable, bloc et argile 14 pi (4.3m)

Dolomitic limestone 26 ft (8m)
Calcaire dolomitique 26 ft (8m)

Sandstone 7ft (2.2m)
Grès 7 pi (2.2m)

Bedrock (rhyolite)
Socle rocheux (rhyolite)

ROCHE associés ltée Groupe-conseil 2535, boul Laurier, Sainte-Foy, Québec G1V 4M3 Canada (418) 871 9800 Télex : QBC 051 31583	**MINE # 5 MINE**	**Date** 07 - 1985	**Figure** 5.3

5.4 ROCK MASS

. Nature of the Rock

Details of the rock mass are as follows:

Footwall :	fragmented rhyolite and andesite
Deposit :	massive sulfides
Hanging wall:	fragmented rhyolite and altered dacite

Water infiltration through the rock mass has produced the following alterations:

- kaolinization and increase of the porosity of the walls (to a depth of 200 ft: 60m).

- accentuated oxidation to a depth of 20 ft (6m) deep.

Also, a zone of chloritization and sericitazation runs through the immediate walls.

. Structural Geology

No major discontinuity has been observed in the deposit or in the immediate walls. Two families of joints are located in the walls about one to two ft (0.3 - 0.6m) apart. The first joint family strikes N-S with an average dip of 70°E and the second follows a NE-SW direction with an average dip of 86° to the SE.

No filling material has been observed in the joints; these are generally tight with dry or slightly damp walls.

According to information coming from a mine situated about 60 km from the property visited, the major principal stress strikes NS and is practically horizontal. This stress is estimated at about 3 000 psi (21 MPa), at 3 200 ft (975 m) below the surface. The horizontal/vertical stress ratio is evaluated at 2.

The interface of the walls and the deposit is clean, especially in the alteration zone (0-200 ft: 0-60 m deep). In this zone the kaolinized rhyolite is more fragile than the deposit.

. Characteristics

None of the geomechanical properties of the rock mass have been determined in this mine. R.Q.D. ratings and geomechanical classifications were not used.

The density of the rock was estimated at 2.77 for the walls and at 3.2 - 4.0 for the disseminated and massive sulfides.

5.5 HYDROGEOLOGICAL CONDITIONS

. Overburden

Surface precipitation has no noticeable influence on the amount of water pumped from the mine. The water level in the soil is much the same as that in the neighbouring lake. The boring of the shaft provided an excellent opportunity for examining the soils and the hydrogeological conditions of the mining property. At the beginning of operations, two holes were drilled as far as the host rock and permeability tests were carried out at intervals of 10 ft (3 m). At depths of more than 72 ft (22m), the ground would no longer absorb the water injected into the drill hole. Originally, the plan was to seat the neck of the shaft in the basal sandstone, running through the soils and dolomitic limestone. Later, because of the poor ground conditions encountered, the neck was lowered to 62 ft (19m). Wooden frames were installed at the level of the dolomitic limestone as it was much more fractured than expected. Despite an injection of shotcrete around the collar, water managed to filter through. At the level of the dolomitic limestone, water output was estimated at 40 (US)GPM (2,5 L/s) at the level of basal sandstone it reached 400 (US) GPM (25 L/s). A network of 12 holes drilled around the shaft, followed by an intensive shotcrete program reduced the water flow from 400 to 35 (US)GPM.

. Rock Mass

The average annual rate of pumping in the mine is estimated at 175 (US)GPM.

5.6 MINING OPERATIONS

. Mining Methods

Some sections of the deposit are worked using the shrinkage stoping method, but, in general, exploitation is carried out with the VCR method which has been successfully used in two other mines in the area. The upper stope was worked through shrinkage stoping. Sill pillars are left every 180 ft (55 m).

. Operating Conditions

With the VCR method, holes 6½ in (16.5 cm) in diameter and 160 ft (49 m) long are drilled according to a 10x10 ft (3 by 3) pattern. Blasting is done in sections 8 ft (2.4m) thick; a powder factor of 10 lbs/t (4.5 kg/t) is generally used.

In the upper stope, extraction is estimated at about 85% with a dilution of 20% caused by boulders falling from the hanging wall.

Currently, the surface pillar is about 246 ft (75 m) thick, including the Ordovician rock. An attempt to exploit the upper part of the deposit failed; a drift opened at level 45 had to be abandonned because of the poor quality of the walls.

The mining sequence in the stopes is from bottom to top and, in the mine overal, from top to bottom.

5.7 SUPPORT AND REINFORCEMENT METHODS

. Primary Support

In the upper stope, no pillar has been left as primary support.

. Filling and Reinforcement

No filling has been effectuated in the stopes already exploited. In general, the walls and crowns need no reinforcement, except in a few places where there is scaling of the walls. In these cases, traditional bolts (90%), resin-anchored bolts and swellex stabilizers (10%) are used. Management expects to use the swellex-type bolts increasingly. Cables and shotcrete are sometimes used in special cases.

Wooden frames were used mainly at level 45 (upper stope) to keep the openings useable.

5.8 MONITORING PROGRAM(S)

. Stress measurements

No stress measurements have been taken in this mine.

. Displacement measurements

No displacement measurements have been taken in this mine.

. Other programs

Except for daily visual inspections carried out by the foremen, no specific monitoring program has been initiated by mine management.

5.9 SURFACE PILLAR DESIGN

. Personnel Involved

The design of the pillars is the responsibility of the Chief Engineer from the Mine Engineering Department. He examines solutions put forward by the Planning Engineers and then discusses these solutions with the Geologists and the Chief Engineer of the mine. When a solution is reached, it is submitted to the Mine Superintendent for final approval. Figure 5.4 shows the different persons involved in pillar design. No special study has been conducted on surface pillars, either by the Company or by an outside consultant.

. Chronology

The eventual exploitation of the surface pillar was not considered a possibility when it was designed. Now, mine management is looking into different possibilities of working the pillar. The main problem is the low competence of the rock in the upper part of the mine.

. Design Factors

The original design of the surface pillar was based on information obtained from exploitation programs (drill holes) and from the boring of the shaft, and also on the practical experience of mine personnel. No theoretical model was used for sizing the pillar: the thickness was

ORGANIZATION CHART - PILLARS DESIGN
ORGANIGRAMME - CONCEPTION DES PILIERS

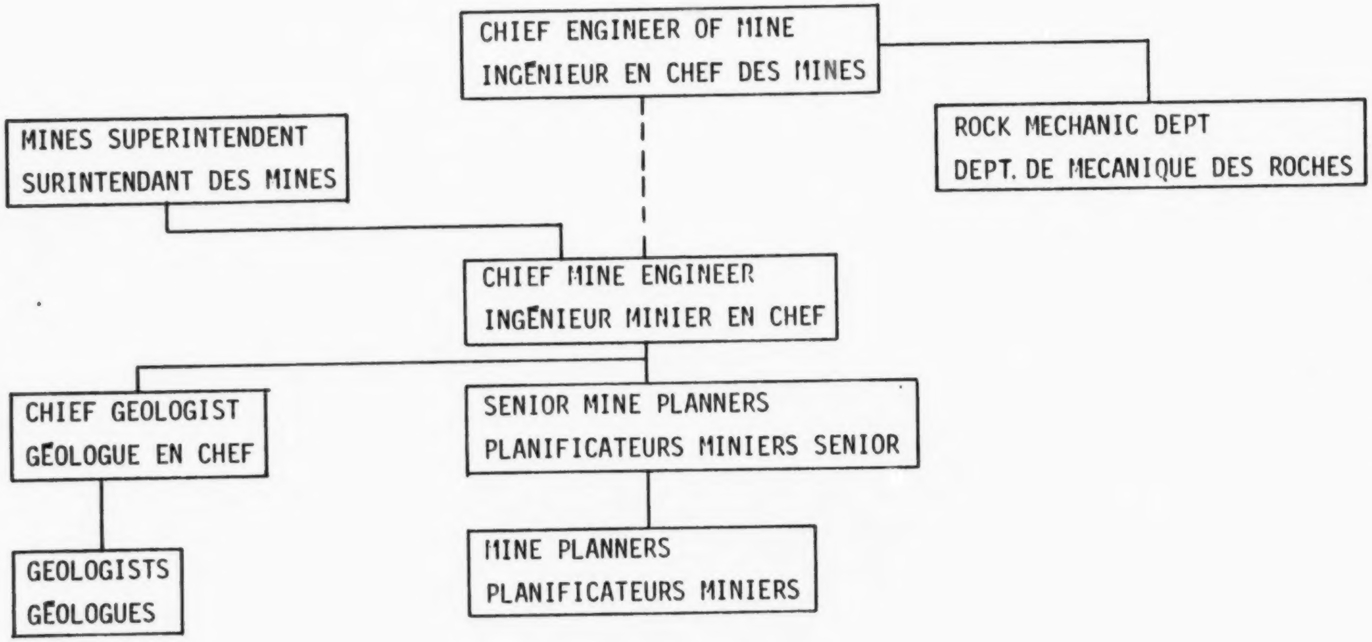

CHIEF ENGINEER OF MINE
INGÉNIEUR EN CHEF DES MINES
ROCK MECHANIC DEPT
DEPT. DE MECANIQUE DES ROCHES
MINES SUPERINTENDENT
SURINTENDANT DES MINES
CHIEF MINE ENGINEER
INGÉNIEUR MINIER EN CHEF
CHIEF GEOLOGIST
GÉOLOGUE EN CHEF
SENIOR MINE PLANNERS
PLANIFICATEURS MINIERS SENIOR
GEOLOGISTS
GÉOLOGUES
MINE PLANNERS
PLANIFICATEURS MINIERS

Figure 5.4

arrived at by taking into consideration the fractured zones situated near the surface and the presence of permeable sandstone between the mine and the lake.

. Pillar dimensions

Table 5.1 shows the dimensions of the surface pillar and of the underlying stope.

DIMENSIONS OF SURFACE CROWN PILLARS

DIMENSIONS DES PILIERS DE SURFACE

TABLE 5.1
TABLEAU 5.1

DIMENSIONS		PILLARS - PILIERS							
		#1							
. THICKNESS: EPAISSEUR:									
- WATER BODY PLANS D'EAU	feet-pi. (m)	-							
- OVERBURDEN MORTS-TERRAINS	feet-pi. (m)	14 (4,3)							
. SURFACE CROWN PILLAR: PILIER DE SURFACE:									
- THICKNESS EPAISSEUR	feet-pi. (m)	110 (34)							
- WIDTH LARGEUR	feet-pi. (m)	20-45 (6-14)							
- LENGTH LONGUEUR	feet-pi. (m)	290 (88)							
- THICKNESS/WIDTH RATIO RAPPORT EPAISSEUR/LARGEUR		15 (4,6)							
. STOPE HEIGHT HAUTEUR DU CHANTIER	feet-pi. (m)								
. FILL HEIGHT HAUTEUR DU REMBLAI	feet-pi. (m)	-							

5.10 VISUAL EVALUATION OF THE SURFACE PILLAR(S)

The visit to level 45 of zone 1 allowed us to have access to the upper section of the first stope originally planned for exploitation. The opening is approximately 30 ft (9 m) wide, 290 (88 m) long and varies in height from 16 to 18 ft (4.9 - 5.5 m). The section is drafted in Figure 5.2.

Aside from the access drift linking the stope to the mine shaft, several exploitation drifts of approximately 12 ft (3.6 m) in length were drilled into the hanging wall of the deposit, thereby exposing part of the altered rhyolite zone. The longest of these runs some 30 ft (3.6 m).

The roof of this ore-bearing overcut appeared to be very stable in spite of its unsupported span. The massive sulfides show little fracturing and are well cemented together. The stability of the roof is assured by suface scaling, followed by conventional bolting using 5 ft (1.5 m) mechanical anchor bolts installed where needed.
At this level, the two walls are composed of the same types of rocks: sericitized and highly kaolinized altered rhyolite. Given the 70 to 75^{0}E dip of the deposit, the hanging wall is more likely to deteriorate than the footwall, however. It is visually apparent than the scaling of certain parts of the walls is more pronounced on the eastern side, i.e in the hanging wall.

The presence of cross cuts facilitates the localization of two (2) families of main joints as described in section 5.4; these joints strike NS and NE-SW with dips of 70^{0}E and 86^{0}SE, respectively.

A third series of sub-horizontal joints intersect the other two; their strike is NS with 20-25^0 dip, thus cutting triangular blocks.

The combination of these three groups of joints favours the formation of serrated roofs in the drifts striking NE-SW. The cohesion of these weak planes seems to be very low; this can evidently be attributed to the presence of alternation material combined with a certain degree of humidity (the water acts as a lubricant int he cross cuts). In fact, numerous triangular blocks have slid from the walls and roof.

In the same line of thought, the mine's management had sets of timber installed in the longest lateral drift, approximately 30 ft (9 m) in length. In spite of this action, the drift was condemned and a high compressing of the posts is evident - a clear sign of the structural slacking in this zone.

Overall, there is little water in this stope in spite of the presence of a significant aquiferous horizon that helps to minimize the deterioration of the walls. It is thereforre easy to understand why management decided not to mine this stope as initially intented, but to leave an additional 150 ft (46 m) as a surface pillar. Recall, however, that this falls within the "VCR" mining method with stopes of 160 ft (49 m) high using neither pillar nor fill. For now, no other approach has been studied in detail.

5.11 MANAGEMENT'S COMMENTS

Mine management feels that a compilation of the ratios of the stope expanse over the pillar thickness would contribute to a better sizing of surface pillars. At the exploration stage, the R.Q.D. ratings should be increasingly calculated and indicated on the plans and cross-sections of the deposit. This would provide an idea of the geostructural problems the operators might encounter during the boring of the shafts and drifts.

The use of fill should be considered for the working of pillars left in the primary stopes. This solution is being contemplated more and more to increase production and decrease the risk of accidents.

A geomechanical model is currently in use in another of the Company's mines, where the behavior of a shaft pillar has been simulated on a computerized model. The Company expects to extend this type of study to surface pillars.

MINE #6

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6.0 SUMMARY OF THE VISIT

The deposit is composed of four (4) principal veins of gold-bearing quartz, of variable length and strike, divided into zones A, B, F & G.

Generally, the rock mass reaches the surface over all the stopes except in Zone F where a considerable thickness covers the underlying stopes.

Two families of joints have been observed at this mining site and a major fault crosses the property on a northwest axis.

The upper stopes were worked with the non filled open stope method. The thickness of the surface pillars ranges between 25 and 250 ft (7.6 and 76 m) from one stope to another.

Toward the end of 1983, a series of rockbursts occured in Zone F and continued for a period of 12 days. Because of this, almost all support methods are being used in the stopes. Also, in order to control the overly high concentration of stress in the pillars, a program has been initiated.

At the time of the surface pillar design, only Zone F represented any potential danger because of the thickness of the overburden covering it. The soil/rock interface was therefore carefully determined by means of diamond drilling and a line of seismic refraction.

On the other hand, there has been no study of the rock mass for calculation of the sizing of the pillars. They were thus designed according to criteria based on a practical approach and depending on the experience of mine personnel.

6.1 GENERAL INFORMATION

. Regional Geology

The mine is located in the Superior Province in a sequence of Precambrian metavolcanic rocks, surrounded by metamorphic and igneous felsic rocks.

A major fault striking EW borders the metasedimentary sequence at about 25 mi (40 km) south of the mining property. The region is characterized by the metamorphic facies of green schists.

. Local Geology

The rock of the mining property is mainly composed of andesite, chlorite and dacite. Units of ultra-mafic rock cut across the andesite creating deformations which allowed the penetration of mineralized hydrothermal solutions. Veins of quartz and gold-bearing carbonates intersect the rock. Narrow acid and basic dykes cut across the volcanic rock in places. Thin layers of fragmented and silicified tuff accompany the andesite and dacite.

The rock formations on the mining property strike NW with a sharp SW dip (65°-75°).

The physical characteristics of the four (4) zones are:

Zone	Length	Width	Dip
1	1 335 ft (407 m)	5 - 6 ft (1.5-1.8 m)	78-90°
2	680 ft (207 m)	5 - 7 ft (1.5-2.1 m)	70-80°
3	3 345 ft (1 020 m)	4 - 7 ft (1.2 - 2.1m)	85-87°
4	1 130 ft (344 m)	11 - 25 ft (3.3 - 7.6m)	72-75°

Gold is the principal ore exploited. The average content of gold is 0.57 oz/t with traces of silver.

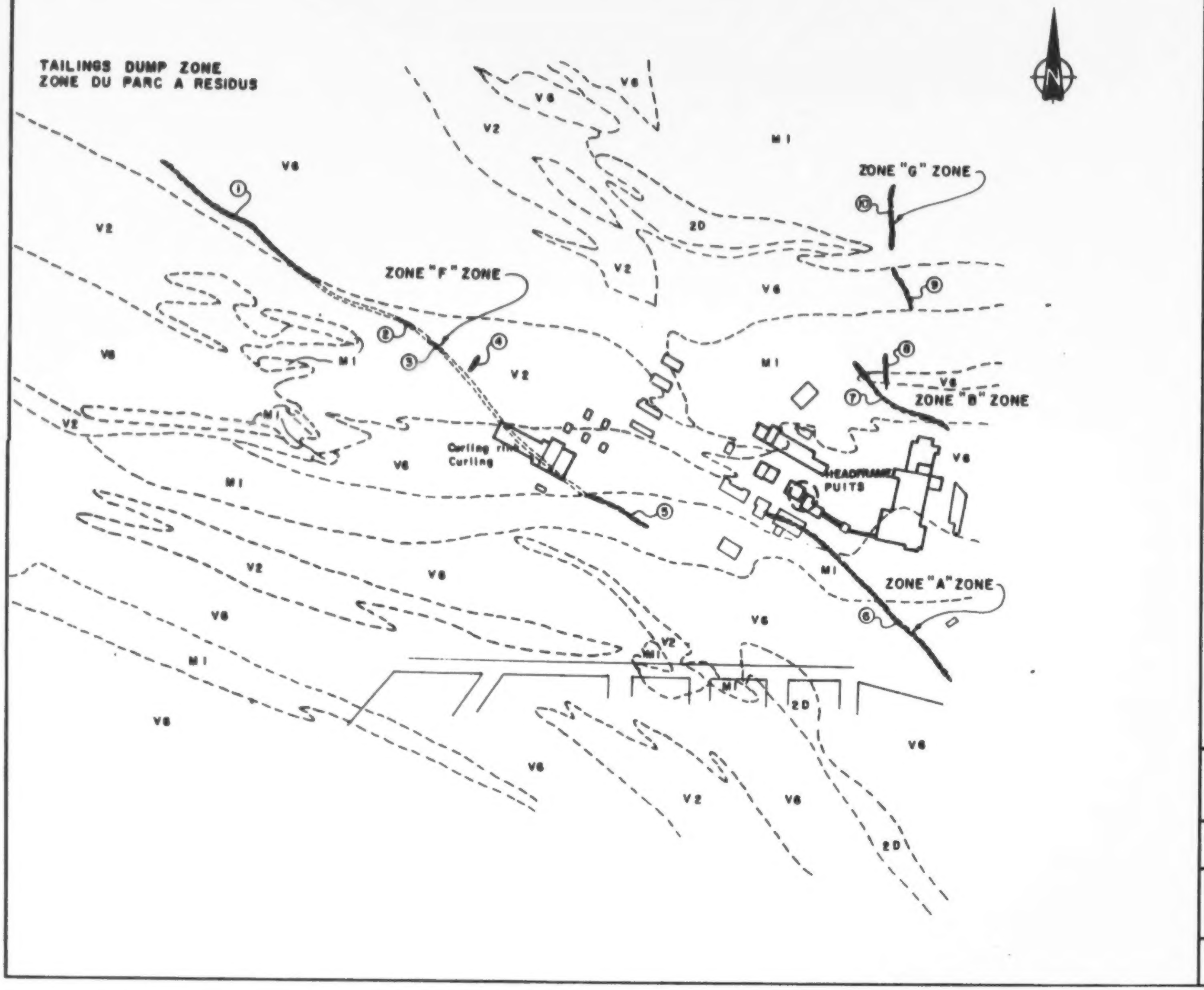
Gold production has been continuous since 1949 and currently, about 1 000 tons are extracted from the mine daily.

. Characteristics of the Deposit

The ore is composed of veins of gold-bearing quartz, generally contained in andesite. Several relalively continuous ore veins of variable lengths criss-cross the proprerty. Of these numerous veins, only four (4) rise to the surface and are economically viable. These four ore zones require surface pillars and are identified by the letters A, B, F and G (see Figure 6.1). Inside these zones the ore is discontinuous or interspersed with waste zones, which implies ten (10) surface pillars of lengths between 90 and 1335 ft (27 - 407 m).

Two types of ore are typical of the mine:

- Veins of gold-bearing quartz: sectors A and F parallel to the formation
- Replacement-type veins: sectors B and G, at the interface between the altered rock and the andesite.



TAILINGS DUMP ZONE
ZONE DU PARC A RESIDUS
ZONE "F" ZONE
ZONE "G" ZONE
ZONE "B" ZONE
ZONE "A" ZONE
HEADFRAME
PUITS
Curling rink
Curling
①
②
③
④
⑤
⑥
⑦
⑧
⑨
⑩
V2
V6
M1
2D
N

LEGEND - LEGENDE

V2	Rhyolite Rhyolite
V6	Andesite Andésite
M1	Schist Schiste
2D	Diorite Diorite
③	Stope Chantier

NOTE FOURTEENTH LEVEL GEOLOGY
GEOLOGIE DU 14e NIVEAU.

0 500
feet - pieds

ROCHE
associés ltée
Groupe conseil

2535 boul Laurier,
Sainte-Foy Québec
G1V 4M3 Canada
(418) 871 9800
Télex 051 31985

MINE #6 MINE

SURFACE PLAN
PLAN DE SURFACE

Date 07/85

Figure 6.1

6.2 MINING ENVIRONMENT

Immediately above the narrowest zones (A,B and F) are several surface installations: a recreation center, a parking lot, part of a treatment plant, a drying shed and a road. The western sector of zone F, which was previously covered with swamp, has recently been used as a tailings dump.

We should mention that before dumping waste over the western portion of zone F, the mine authorities had a seismic reading done to determine the rock profile overlying the upper stopes of the zone (see section 6.3).

Another mining property is located adjacent to this mine; however, a 20 ft (m) pillar has been left between the two. This mine is actually a continuation of the deposit.

The adjacent part of the neighbouring mine is composed of stopes which were opened and mined during the 1950's.

6.3 OVERBURDEN

. Studies

No geotechnical study has been conducted on this property.

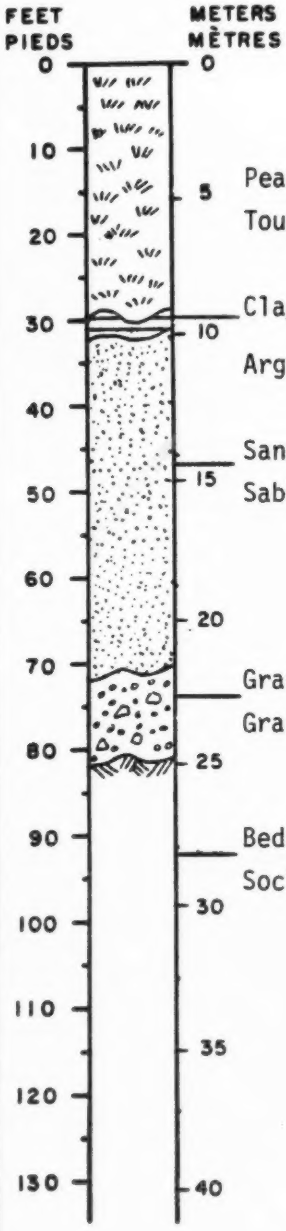
A few diamond drillings have been effectuated to evaluate rock topography. Also, a seismic refraction reading line has been completed directly over the western stopes of zone F. Thus, a length of about 2 100 ft (640 m) was covered using a series of twelve (12) geophones spaced at intervals of 70 ft (21 m) and displaced three (3) times along the longitudinal axis of the deposit. The results indicate that the rock-overburden contact is relatively constant along the entire length of the cover. In some places only, there are depressions of about 25 ft (8 m). According to mine management, the precision of the results based on diamond drilling is in the order of plus or minus 20%. The rock skims the surface over all the stopes except those of zone F which are covered by a respectable thickness of overburden (82 ft, 25m).

. Stratigraphy and Characteristics

Soil stratigraphy over zone F is illustrated in Figure 6.2. The density of the soils situated beneath the swampy area is estimated at 130 lbs/pi^3 (20 KN/m^3).

In management's opinion, the soil is not very cohesive and is completely saturated. This soil is located in a natural depression; as a result, this soil could very well seep into the underlying stopes should there be a cave-in of the surface pillars.

SOIL STRATIGRAPHY
STRATIGRAPHIE DU SOL


FEET
PIEDS
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120
130
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10
15
20
25
30
35
40

Peatmoss and water	30 ft (9.1m)
Tourbe et eau	30 pi (9.1m)
Clay	2 ft (0.6m)
Argile	2 pi (0.6m)
Sand	40 ft (12.2m)
Sable	40 pi (12.2m)
Gravel and boulders	10 ft (3m)
Gravier et blocs	10 pi (3m)
Bedrock	
Socle rocheux	

		Date	Figure
ROCHE associés ltée Groupe-conseil 2535, boul Laurier, Sainte-Foy, Québec G1V 4M3 Canada (418) 871 9600 Télex : QBC 051 31593	**MINE # 6 MINE**	07-1985	6.2

6.4 ROCK MASS

. Nature of the Rock

Details of the rock mass are as follows:

Footwall : Andesite

Deposit :- veins of quartz and gold-bearing carbonates

- replacement veins located at the interface of andesite and rock altered to chloritic schist.

Hanging wall: Andesite and sometimes chloritic schist (zone G).

The alteration is represented by zones of carbonization, silicification and sometimes chloritization around the ore veins. No oxidation zone has been observed near the surface.

. Structural Geology

The veins are sub-vertical and generally follow the strike of the metavolcanic rock (NW-SE, 75° S). The foliation is parallel to veins A and F and intersects veins B and G.

Two families of joints have been observed on the mining site. Mine management states that these joints are continuous, smooth and normally dry.

A major fault containing fill material runs through the mine property in a N-W direction and dips (65-70°) to the south.

Field tests done in this mine show that natural horizontal stress is about 1 200 psi (8.3 MPa). The ratio of horizontal to vertical stress is estimated at about 2.

. Characteristics

The geomechanical properties of the rock mass are indicated in Table 6.1.

No R.Q.D. rating has been calculated in the upper levels. However, for about a year, this rating has been calculated at strategic points in the lower levels.

No geomechanical classification is used in this mine.

Sound velocity in the rock is 19 260 ft/s (5 870 m/s) at the surface and 22 200 ft/s (6 770 m/s) at the lower levels.

The acoustic activity of the andesite varies between 50 and 100% with an average of 76% and the chloritic schist ranges between 64 and 100% with an average of 82%.

The andesite is very brittle.

ROCK CHARACTERISTICS

CARACTÉRISTIQUES DE LA ROCHE

TABLE 6.1

TABLEAU 6.1

LOCATION EMPLACEMENT		FOOT WALL ÉPONTE INFÉRIEURE	OREBODY GISEMENT	HANGING WALL ÉPONTE SUPÉRIEURE	
ROCK TYPE TYPE DE ROCHE		ANDESITE ANDESITE		ANDESITE ANDESITE	CHLORITIC SCHIST SCHISTE CHLORITIQUE
DENSITY DENSITÉ		2.82		2.82	-
COMPRESSIVE STRENGTH RÉSISTANCE EN COMPRESSION	psi x 10^3 (MPa)	34 (234)		34 (234)	17 (117)
SHEAR STRENGTH RÉSISTANCE AU CISAILLEMENT	psi x 10^3 (MPa)	8 (55)		8 (55)	
TENSILE STRENGTH RÉSISTANCE EN TENSION	psi x 10^3 (MPa)	3 (21)		3 (21)	
POINT LOAD STRENGTH INDICE DE DOUBLE POINCONNEMENT	psi x 10^3 (MPa)				
POISSON'S RATIO RAPPORT DE POISSON		0,21		0,21	0,15
YOUNG'S MODULUS MODULE DE YOUNG	psi x 10^6 (GPa)	12 (83)		12 (83)	8 (55)
RQD %		85-90		85-90	
GEOMECHANICAL CLASSIFICATION CLASSIFICATION GÉOMÉCANIQUE					

6.5 HYDROGEOLOGICAL CONDITIONS

- Overburden

No water has been observed at the surface except in the area of the tailings dump.

- Rock Mass

An average continuous flow of 150 (US)GPM (9.5 L/s) is pumped from the mine. No seasonal variation has been observed.

Mine management states that there was an increase in water infiltration below the tailing dump area at the time it was put into service. Later, the infiltration ceased. According to mine management, drill holes bored during the exploitation program probably caused this infiltration but were later gradually plugged with mine tailings and various materials.

6.6 MINING OPERATIONS

. Mining Methods

The following mining methods were used according to the level worked:

Depth	Level	Mining Methods Shrinkage Stoping	Cut-and-fill
0-1000 ft	0-7	100%	0%
1000-2000 ft (305-610 m)	7-14	60%	40%
2000 ft (610 m)	15...	0%	100%

The cut-and-fill method, introduced in the mine at the beginning of the 1960's, has been increasingly used, and since 1982 exceeds in percentage the use of the shrinkage stoping method.

. Operating Conditions

The upper stopes were worked gradually from the bottom towards the top. The thickness of the surface pillars varies from one stope to another between 25 and 250 ft (7.6 - 76 m). The extraction rate for these stopes was close to 100%.

No data on dilution has been supplied, but it must have been minimal as the walls are sufficiently competent to prevent any scaling.

The mining sequence is from top to bottom in the mine overall, but from bottom to top inside the stopes.

The upper stopes and most of those situated between the second (2nd) and the fourteenth (14th) levels are still open. Below the 14th level, they were normally filled within a month of being closed.

Spacing between the levels varies in the upper part of the mine. From the surface to the third level, the spacing is 25 ft (38m) and for the lower levels it is 150 ft (46 m).

6.7 SUPPORT AND REINFORCEMENT METHODS

. Primary Support

The upper stopes have no wall pillars and have not been filled.

. Filling and Reinforcement

In the lower stopes, rockbursts are frequent; in order to decrease their frequency, the stopes are filled and bolts systematically installed. The fill is a mix of water, mine tailings and cement.

Because of numerous strong rockbursts which occurred in zone F over a twelve (12) day period towards the end of 1983, almost all reinforcement techniques are now used in the lower stopes: conventional bolts, grouted and resin-anchored steel rebars, steel mesh, shotcrete, wooden frames, grouted cables, etc.

It should be noted that in those zones surrounding the drawing points which suffered rockbursts, the pillars are being increasingly replaced by wooden frames.

The highly brittle and elastic nature of the andesite is the principal factor contributing to the violent ruptures of the pillars.

6.8 MONOTORING PROGRAM(S)

. Stress Measurements

No stress measurements have been taken at the surface pillar level. "In situ" stress was determined at a lower level.

. Displacement Measurements

Because of stress concentrations that are too high in certain pillars located in the lower levels, the mine's management has begun a program aimed at easing these pillars by working directly on them with blasting and reinforcement techniques. Extensometers were used to record displacements caused by these operations. The displacements measured were not as significant as might have been anticipated from the model.

No displacement measurements have been taken at the upper level.

To detect rockbursts, a multi-channel microseismic system covering several lower levels was installed about two years ago. Thanks to this system, management can follow the energy output from the rock mass, particularly in the pillars, and can take preventive action should significant seismic tremors be detected.

No visual inspection program is pursued for the upper stopes.

6.9 SURFACE PILLAR DESIGN

. Personnel Involved

Surface pillar design is initiated by the Chief Mine Engineer and the Planning Engineer. The Engineer in charge of Rock Mechanics and the Chief Geologist are consulted on sizing and on the identification of areas of weakness. In the case of major pillars, such as surface pillars, the General Superintendent and the Mine Manager approve or modify the suggested design procedure. Figure 6.3 shows the personnel involved in pillar design.

External consultants have been asked for opinions on the rockbursts and on the sizing of certain pillars. None of the latter, however, are surface pillars.

As it is, no specific study has been conducted on the surface pillars.

. Chronology

No particular approach based on analytical calculations and/or geostructural studies of the rock mass have been used in the sizing of the surface pillars.

Diamond drilling holes and a seismic refraction line provided precise information on the soil/rock interface above zone F.

No changes have been made in the initial design of the surface pillars.

ORGANIZATION CHART - PILLARS DESIGN
ORGANIGRAMME - CONCEPTION DES PILIERS

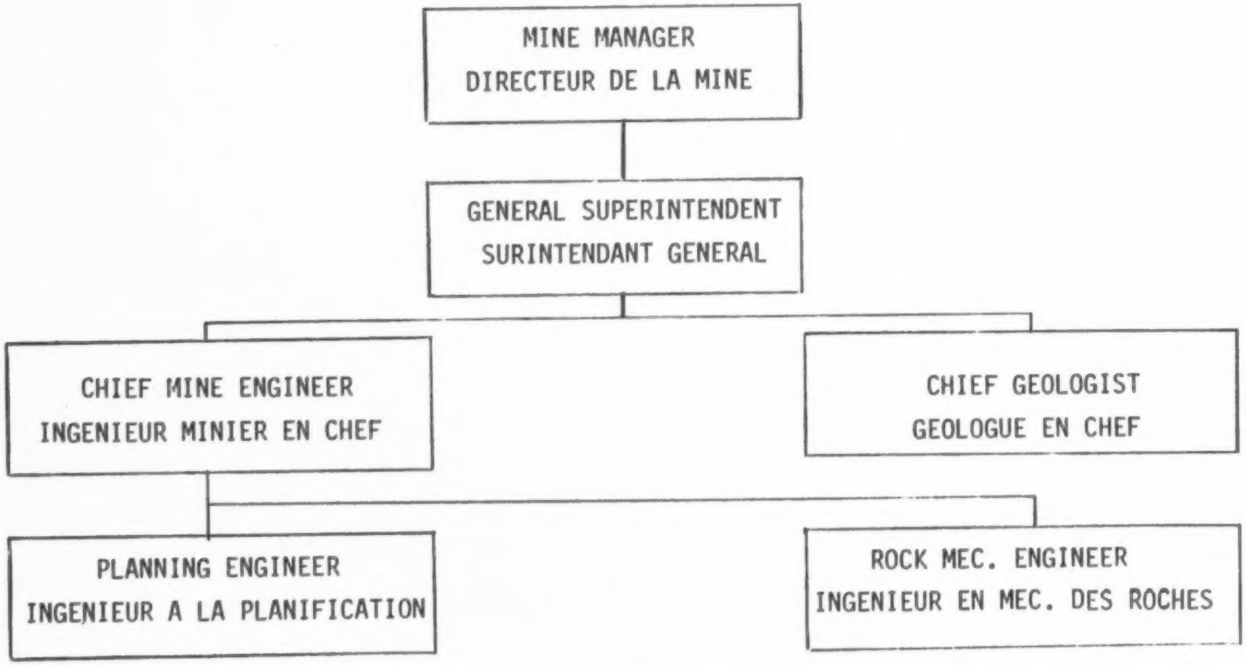
MINE MANAGER
DIRECTEUR DE LA MINE
GENERAL SUPERINTENDENT
SURINTENDANT GENERAL
CHIEF MINE ENGINEER
INGENIEUR MINIER EN CHEF
CHIEF GEOLOGIST
GEOLOGUE EN CHEF
PLANNING ENGINEER
INGENIEUR A LA PLANIFICATION
ROCK MEC. ENGINEER
INGENIEUR EN MEC. DES ROCHES

Figure 6.3

. Design Factors

The design criteria may be summed up as a practical approach based on the experience of mine personnel. It should be noted that the strength of the pillars of the lower stopes may be evaluated using the following empirical formula:

$$Qu = 100 \frac{W^{0.5}}{H^{0.75}}$$

where Qu = strength of the pillar in MPa

W = width of the pillar

H = height of the pillar

100 = constant (a function of laboratory test and sample sizes)

. Pillar dimensions

Table 6.2 gives the dimensions of the surface pillars covering zones A, B, F and G.

DIMENSIONS OF SURFACE CROWN PILLARS

DIMENSIONS DES PILIERS DE SURFACE

TABLE 6.2
TABLEAU 6.2

DIMENSIONS		PILLARS - PILIERS							
		#1	#2	#3	#4	#5	#6	#7	#8
. THICKNESS: EPAISSEUR:									
- WATER BODY PLANS D'EAU	feet-pi. (m)	0	0	0	0	0	0	0	0
- OVERBURDEN MORTS-TERRAINS	feet-pi. (m)	70 (21,3)	60 (18,3)	60 (18,3)	45 (13,2)	0	0	0	0
. SURFACE CROWN PILLAR: PILIER DE SURFACE:									
- THICKNESS EPAISSEUR	feet-pi. (m)	150 (46)	225 (68)	225 (68)	60 (18)	40 (12)	30 (9)	55 (17)	27 (8)
- WIDTH LARGEUR	feet-pi. (m)	5,7 (2)	5,7 (2)	5,7 (2)	35 (10,7)	5,7 (2)	5,5 (2)	6 (2)	18 (5,5)
- LENGTH LONGUEUR	feet-pi. (m)	890 (271,3)	90 (27,4)	135 (41,2)	220 (67,1)	340 (103,7)	1 335 (407,0)	680 (207,3)	200 (61,0)
- THICKNESS/WIDTH RATIO RAPPORT EPAISSEUR/LARGEUR		26,0	39,5	39,8	1,7	7,0	5,5	9,2	1,5
. STOPE HEIGHT HAUTEUR DU CHANTIER	feet-pi. (m)	320 (115,9)	170 (151,8)	170 (151,8)	110 (33,5)	330 (100,6)	450 (137,2	230 (70,1)	600 (182,9)
. FILL HEIGHT HAUTEUR DU REMBLAI	feet-pi. (m)	0	0	0	0	0	0	0	0

DIMENSIONS OF SURFACE CROWN PILLARS

DIMENSIONS DES PILIERS DE SURFACE

TABLE 6,2
TABLEAU 6,2

DIMENSIONS		PILLARS - PILIERS							
		#9	#10						
. THICKNESS: EPAISSEUR:									
- WATER BODY PLANS D'EAU	feet-pi. (m)	-	-						
- OVERBURDEN MORTS-TERRAINS	feet-pi. (m)	15 (4,6)	-						
. SURFACE CROWN PILLAR: PILIER DE SURFACE:									
- THICKNESS EPAISSEUR	feet-pi. (m)	43 (13)	40 (12)						
- WIDTH LARGEUR	feet-pi. (m)	18 (5,5)	18 (5,5)						
- LENGTH LONGUEUR	feet-pi. (m)	215 (65,5)	345 (105,2)						
- THICKNESS/WIDTH RATIO RAPPORT EPAISSEUR/LARGEUR		2,4	2,2						
. STOPE HEIGHT HAUTEUR DU CHANTIER	feet-pi. (m)	7,0 (21,3)	340 (103,7)						
. FILL HEIGHT HAUTEUR DU REMBLAI	feet-pi. (m)	-	-						

6.10 VISUAL EVALUATION OF THE SURFACE PILLAR(S)

It is not possible to reach the area under the surface pillars because of the wide gaps left by the open stopes.

It was nevertheless possible to appreciate the high degree of competence of the rock, the low level of fracturing (RQD 85%) and nearly total absence of underground water infiltration in the upper stopes of the mine. Structurally, this type of rock represents no problems of instability. Moreover, the strength of the rock is higher than the existing stresses, thereby assuring the stability of the gaps - at least to a depth of 600 - 700 ft (180-210 m). Below this level, as already indicated, numerous rockbursts have occured.

6.11 MANAGEMENT'S COMMENTS

Overall, the personnel of this mine work on very brittle ground; they are therefore very preoccupied with determining the true strength of the rock when submitted to conditions of limited stress. They would like to see the development of empirical formulae linking these two factors.

In another line of thought, there would be a certain interest in the creation of data banks on soil and rock if these were accessible to operators.

MINE #7

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7.0 SUMMARY OF THE VISIT

The mine is composed of veins of quartz and auriferous carbonates about 6 ft (2 m) thick. The veins have an acute dip between 75° and 80°.

Since the beginning of operations, no sign of surface settlement has been observed.

A series of drill holes were conducted to determine the soil-rock contact. The rock mass is principally composed of andesite and diorite. Three joint systems are noticeable in the lower mine levels but they become less evident as the higher levels are reached. The surface pillars are generally massive and have little or no apparent structure. Water pressure is almost nil at the higher level but increases with depth. Management's biggest problem is the brittle nature of the rock which causes rockbursts. The use of filling material and the installation of bolts has greatly reduced this problem.

The upper shafts have been worked by open shrinkage stoping. These stopes are very narrow; no rib pillars have been left. The thickness of the surface pillars was arbitrarily set at 40 feet (12 meters) at the start of operations. Presently the average thickness of the surface pillars is 35 feet (11 meters).

A neighbouring underground mine is currently in operation, working a continuation of the same deposit. Barrier pillars have been left on the boundary line between the two properties but there is no connecting underground shaft.

The company has recently initiated a rock mechanics program.

7.1 GENERAL INFORMATION

. Regional Geology

The mine is located in the Superior Province on a metavolcanic rock sequence of Precambrian origin, surrounded by metamorphic and pyrogenic felsite. A major east-west fault borders the metasedimentary sequence about 25 miles (40 km) to the south of the property. The metamorphic facies of green schists is characteristic of the area.

Local Geology

The mining property is mainly composed of andesite (altered basalt) and diorite (figures 7.1 and 7.2). The ore zone is composed of veins of quartz and auriferous carbonates following the north-west flow of the rocks. Dykes of lamprophyre and of porphyric quartz-feldspath also occur along the same axis. A number of folds on a S20°W axis descending at about 60° W can be seen near the mine at the four (4) uppermost levels.

. Mine Caracteristics

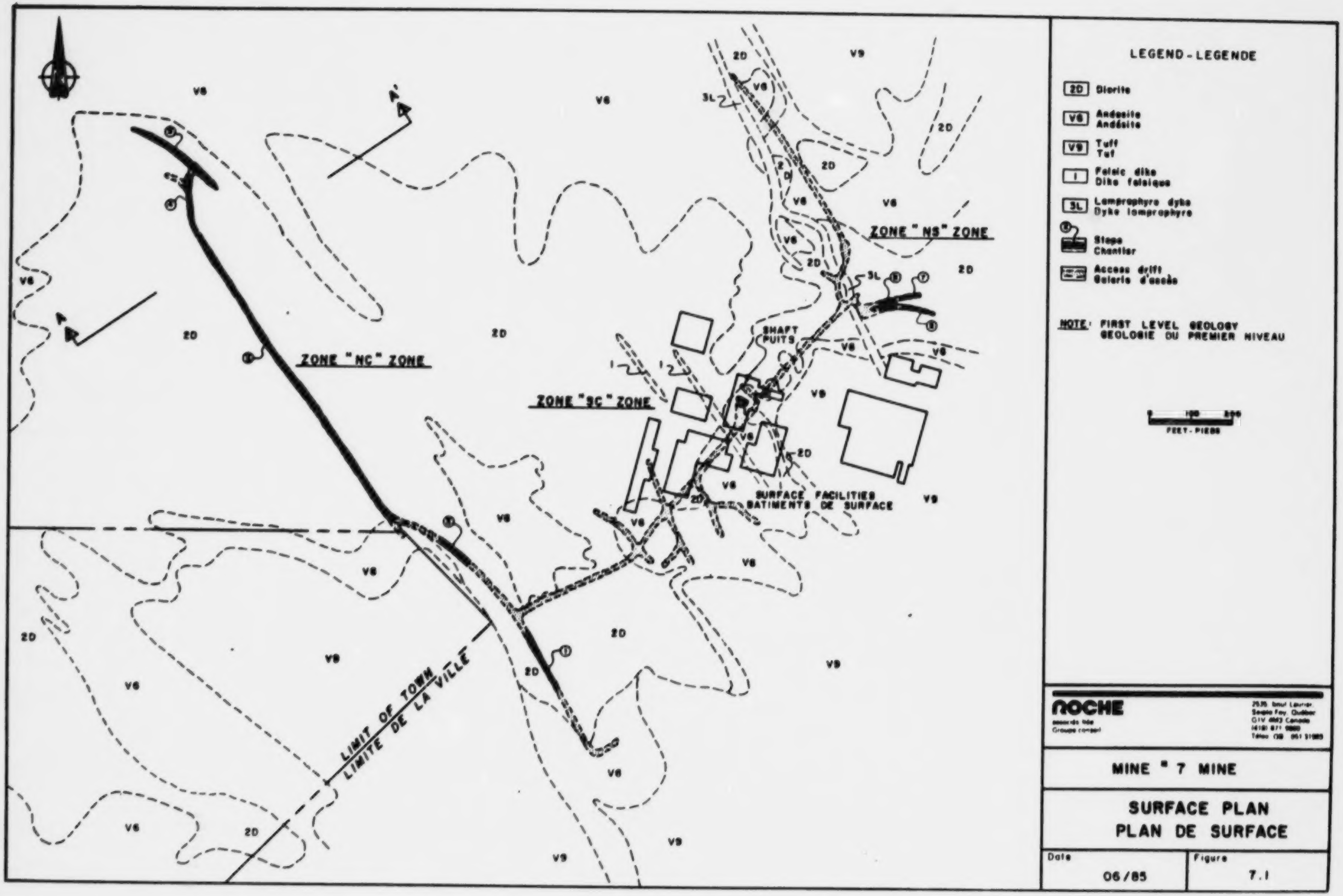
The mine is composed of veins of gold-quartz and sulphides containing disseminated gold. Two precious metals, gold and silver, are mined.

As shown in figures 7.1 and 7.2, the mine is divided into several zones, three of which reach the surface. The dimensions of these three (3) zones are:

		zone "NC"	zone "SC"	zone "NS"
Length	ft	1 700	600	100
	(m)	(520)	(180)	(30)
Width	ft	5	6	6
	(m)	(1.5)	(2)	(2)
Depth	ft	1 100	2 300	500
	(m)	(336)	(700)	(150)

Zones "NC" and "SC" are operational while zone "NS is no longer mined.

The "NC" and "SC" zones dip vertically keeping to a more or less consistent width. From the surface to a depth of more than 2 000 ft (600 m), the veins dip between 75° and 80°. Production is continuous at about 700 t daily.

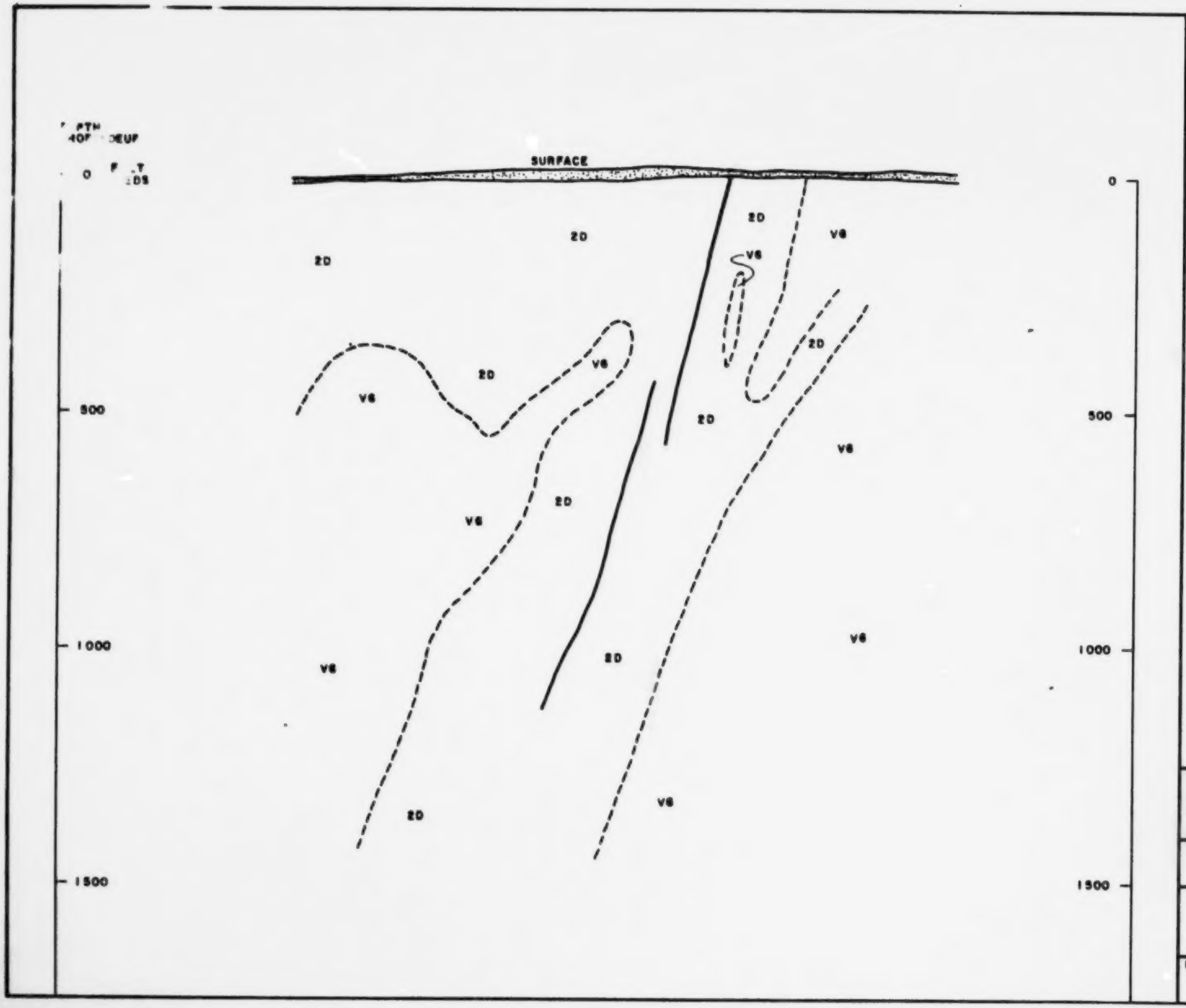

ZONE "NC" ZONE
ZONE "9C" ZONE
ZONE "NS" ZONE
SHAFT
PUITS
SURFACE FACILITIES
BATIMENTS DE SURFACE
LIMIT OF TOWN
LIMITE DE LA VILLE
A
A'
2D
V6
V9
3L
LEGEND-LEGENDE
2D Diorite
V6 Andesite
Andésite
V9 Tuff
Tuf
I Felsic dike
Dike felsique
3L Lamprophyre dyke
Dyke lamprophyre
Stope
Chantier
Access drift
Galerie d'accès
NOTE: FIRST LEVEL GEOLOGY
GEOLOGIE DU PREMIER NIVEAU
0
100
200
FEET-PIEDS
ROCHE
associés ltée
Groupe conseil

MINE # 7 MINE

SURFACE PLAN
PLAN DE SURFACE

Date 06/85

Figure 7.1


PTH
OF DEUP
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SURFACE
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2D
V6
V6
2D
V6
0
500
1000
1500

LEGEND - LEGENDE

- ▨ Quartz - carbonate vein / Veine quartz - carbonate
- V6 Andesite / Andésite
- 2D Diorite

0 100 200
FEET - PIEDS

SECTION / COUPE ' A - A'

MINE # 7 MINE

GEOLOGICAL SECTION
COUPE GEOLOGIQUE

Date	Figure
06/85	7.2

7.2 MINING ENVIRONMENT

The following infrastructures are found above the ore zones:

"NC" Zone	"SC" Zone	"NS" Zone
a road and two ventilation shafts	a city	-

No obvious signs of settlement are visible above the surface pillars.

A neighbouring underground mine is currently in operation covering several hundred feet and descending to more than 3 000 ft (910 m). The shafts of this mine come to within 20 ft (6.1 m) of those of the "NC" Zone at the levels under 1 000 ft (305 m) and at deeper levels; the shafts are separated by barrier pillars 40 ft (12.2 m) thick. The presence of this neighbouring mine poses no particular problem to ordinary operations. There is no underground access between the two mines.

The upper stopes were worked without being filled while the deeper ones were filled as operations progressed.

7.3 OVERBURDEN

. Studies

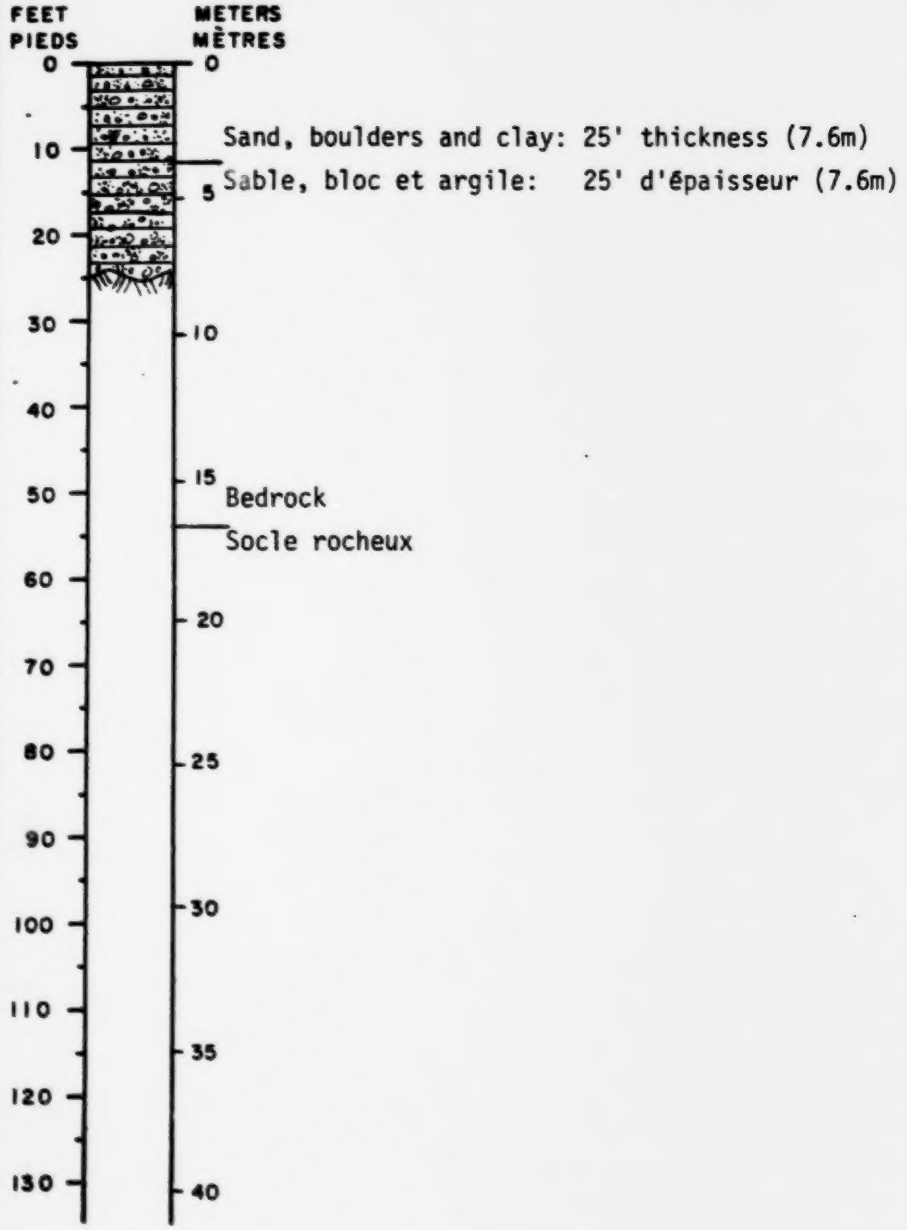
Towards the end of the 1950's, fifteen (15) drill holes were made in the overburden above the "NC" zone. These holes are lined up and spaced at 100 ft, and all stop at 5 ft into the rock. Two trenches dug to monitor the composition of the ore on the surface indicate that ground conditions are fairly stable.

. Stratigraphy and Characteristics

Beneath the surface vegetation, we find glacial deposits composed of sand, boulders and clay. The average thickness of the overburdern covering the "NC" zone is approximately 25 ft (8 m), (see Figure 7.3). Zones "SC" and "NS" are covered by 25 and 15 feet of overburden respectively, similar to that covering the "NC" zone; in the "NS" zone, however, the proportion of clay is higher. As test results are no longer available, the exact composition of the overburden could not be determined.

The overburden on the three zones has undergone no changes; i.e., it has not been removed nor drained with pumps or other surface drying techniques.

SOIL STRATIGRAPHY
STRATIGRAPHIE DU SOL


FEET
PIEDS
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MÈTRES
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10
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50
60
70
80
90
100
110
120
130
0
5
10
15
20
25
30
35
40
Sand, boulders and clay: 25' thickness (7.6m)
Sable, bloc et argile: 25' d'épaisseur (7.6m)
Bedrock
Socle rocheux

ROCHE associés ltée Groupe-conseil 2535, boul Laurier, Sainte-Foy, Québec G1V 4M3 Canada (418) 871 9800 Télex: QBC 051 31593	**MINE # 7 MINE**	**Date** 07-1985	**Figure** 7.3

7.4 ROCK MASS

. Nature of the Rock

The rock mass may be described as follows:

Footwall	: andesite and diorite
Deposit	: veins of quartz and auriferous carbonates
Hanging wall	: andesite and diorite

Near the surface, the veins show an oxidation zone of about 6 ft (2 m). The andesite has been transformed into limonite and rust marks are common in the alteration zone. Glaciers removed most of the oxidized zone and glacial deposits fill the eroded, oxidized area.

. Structural Geology

The rock mass shows three joint systems:
The first system, the largest at about 85%, follows a strike of N45°E at a dip of about 45° towards the north-west.

The second system covers only about 10% of the joints and the planes of discontinuity are subhorizontal.

The third system, the smallest at about 5%, follows more or less the same axis as the first system, but the dip is to the south-east. This causes the formation of pointed blocks.

The three systems are less and less visible towards the surface. The spacing and length of the joints show no continuity and are considerably varied. The angles of the joints are generally less than 1/32 in (0.08cm). Some of these angles or wedges are at times filled with calcite and chlorite. The rupture surfaces are normally smooth and flat. Interstitial water pressure is almost nil in the surface pillars except in the "NS" zone where very slight flows are visible. However, interstitial water pressure is higher in the deeper excavations (lower stopes). The rock mass shows little lineation or foliation. Rocks are mainly massive with few apparent minor structures. Stratigraphic planes are parallel to the ore veins.

Field tests carried out in another mine situated some 10 mi (16 km) to the south west of the mine under study show that the natural horizontal to vertical stress ratio is in a 2:1 proportion.

. Characteristics

The geomechanical properties of the rock mass are illustrated in table 7.1.

The R.Q.D. was not calculated ; the diameter of the drill core was so small that the drilling caused too many fractures for the R.Q.D. to be adequately evaluated.

Some local displacements are apparent in the areas of minor faults through the ore veins. The degree of breakage or fracturing increases with depth as does the frequence of rockbursts. This behaviour is due to the

TABLE 7.1

TABLEAU 7.1

ROCK CHARACTERISTICS

CARACTÉRISTIQUES DE LA ROCHE

LOCATION EMPLACEMENT		FOOT WALL ÉPONTE INFÉRIEURE	OREBODY GISEMENT	HANGING WALL ÉPONTE SUPÉRIEURE
ROCK TYPE TYPE DE ROCHE		Andesite & diorite Andésite & diorite	Gold bearing quartz & carbonate veins Veines de quartz & carbonate aurifères	Andesite & diorite Andésite & diorite
DENSITY DENSITÉ		2.7	2.7 - 2.9	2.7
COMPRESSIVE STRENGTH RÉSISTANCE EN COMPRESSION	psi x 10^3 (MPa)	34± 5 (234±34)	-	34± 5 (234±34)
SHEAR STRENGTH RÉSISTANCE AU CISAILLEMENT	psi x 10^3 (MPa)	-	-	-
TENSILE STRENGTH RÉSISTANCE EN TENSION	psi x 10^3 (MPa)	3.4 (estimated) (23)(estimé)	-	3.4 estimated (23) estimé
POINT LOAD STRENGTH INDICE DE DOUBLE POINCONNEMENT	psi x 10^3 (MPa)	-	-	-
POISSON'S RATIO RAPPORT DE POISSON		0,25	-	0,25
YOUNG'S MODULUS MODULE DE YOUNG	psi x 10^6 (GPa)	12 (83)	-	12 (83)
RQD %		-	-	-
GEOMECHANICAL CLASSIFICATION CLASSIFICATION GÉOMÉCANIQUE		-	-	-

brittleness of the rock which reacts to the increasing induced variations causes by the deeper excavations.

Some tests were carried out with one channel seismic equipment to determine the speed of sound waves in the rock mass. These tests were complicated by the nearness of the many underground excavations which interfere with and modify the speed of sound waves in the rock mass. These speed changes may be attributed to the redistribution of the stress fields along the opening walls. The speeds recorded vary between 8 000 and 12 000 ft/sec (2 400 and 3 600 m/sec) with peaks as high as 19 000 ft/sec (5 700 m/sec). The acoustic activity is betweeen 50 and 100% with an average of 75%: this activity corresponds in percentage to the compressive strength at which an expontential increase in the sound waves emitted by the rock is observed.

7.5 HYDROGEOLOGICAL CONDITIONS

. Overburden

The mining property is located between two lakes, one to the north and the other to the south west. Underground excavations do not reach these lakes. However, the top drifts of the "NS" zone run below a river. Above the "NC" zone, the piezometric level is lower than the overburden-rock contact point since no water is found in the two trenches that reach the rock. No specific study was conducted to determine hydrogeological conditions above the "NS" zone.

. Rock-Mass

About 200 (US)GPM (13 L/s) are pumped from the mine. Most of the water comes from hydraulic fill. The drainage system (holding tanks) is dispersed over 7 levels including the last. Several holes were filled with cement during exploitation, between the third and fourth levels, but no cement was injected in the surface pillars.

The upper levels are almost free of water and the lower levels have very little. The water appears corrosive as bolts and other metal materials installed in the rock become very rusted after one year.

7.6 MINING OPERATIONS

. Mining methods

Prior to 1966, stopes were worked entirely by open shrinkage stoping. Between 1966 and 1975 the cut-and-fill technique gradually replaced the previous method and since 1976 the mine is worked exclusively with the cut-and-fill technique.

With this method, sections of ore 8 ft (2.4 m) thick are extracted and the trenches are filled immediately.

. Operating Conditions

The mining of the upper stopes was done gradually, starting at the bottom and ending some 30 ft from the contact point with the overburden. These stopes were worked using sticks of dynamite. The depth and diameter of the drill holes are respectively 8 feet (2,4 m) and 1¼ in (3.18 cm).

The upper stopes have been worked for more than 25 years and have not been filled. They still show no signs of instability.

Between the upper and lower stopes, the percentage of reserves decreases from 100 to 75%, and the dilution is still generally between 5 and 10%.

7.7 SUPPORT AND REINFORCEMENT METHODS

. Primary Support

No wall pillars have been left in the stopes as the latter were very narrow (5 - 6 ft or 1.5 - 2m).

. Filling and Reinforcement

The main problem at this mine is control of rockbursts. Filling the lower stopes and installing bolts help a great deal to control and reduce rockbursts. Conventional bolts have been used in 90% of the cases while cement cables and casing with timber are used for about 5% each. From level 16, steel mesh covers about 50% of the roof of the lower stopes and shafts. Some traction and shearing tests (torque) were done on the bolts but the results were not available.

The successive fill used in each newly worked stope is composed of a layer of mine tailings 7 ft (2.1 m) thick covered by a 1 ft thick layer of a mixture of mine tailings and cement (ratio 15:1) which makes up the work area floor. At the first levels, the work areas have been braced by wooden structures including the ore chutes and the ceiling of the drifts along the ore veins.

In the upper stopes, wooden beams were placed between the walls to prevent wall caving. In the lower stopes, drainage has been facilitated by the installation of filters made of wooden beams and jute.

Stopes more than 5 000 ft^2 (465 m^2) are equipped with perforated pipes installed in the fill.

The mine tailings used as fill have the following granulometry:

Mesh#	%	Cumulative %
65	10.5	10.5
100	14.0	24.5
150	28.0	52.5
200	14.5	67.0
325	22.0	89.0
-325	11.0	100.0

Since the institution of the cut-and-fill technique, the stability of the stopes seems to have improved according to the personnel interviewed. This method decreases sloughing of the walls and allows recuperation of some of the energy accumulated around the openings. The method also has a reassuring psychological effect on the miners.

7.8 MONITORING PROGRAMS

. Stress Measurement

No stress measurement was taken at this mine.

. Displacement Measurement

A preventive measure on the part of the mining personnel consists of measuring the caving of the walls in the stopes situated at level 16 and below. A "home-made" extensometer is used to detect wall movement. According to mine personnel, the conclusions are difficult to evaluate. Unidentified parameters interfere with the reading of displacement. A study of the discontinuities at the lower levels was undertaken in January 1985, through the use of a DZTAB simulation program, but the results of this study were not available.

. Other programs

Tests using geophysical equipement for the detection of micro-seism, "stress alert", showed little results. Mine management decided to discontinue the use of this equipment as it was causing false alarms. Numerous rockbursts were constantly setting off the alarm system in the lower stopes.

7.9 SURFACE PILLAR DESIGN

. Personnel Involved

According to a staff member, the design of the surface pillars was probably the responsability of the Head Engineer during the working of the upper stopes at the first level. At that time, Geology and Mining were handled together in one Department. Decisions by management and professional staff were mainly based on the experience acquired in other mines with similar characteristics. No particular study has been made on the surface pillars.

Currently the Mine Engineering Department is responsible for pillar design, under a Chief Engineer. A newly created Department of Rock Mechanics is also involved in a pillar design. Figure 7.4 shows the organization chart for surface pillar design.

Because of the potential dangers of rock bursts, the Management of the mine ordered a study of the problem. This study was conducted in 1962-63 and one of its principal recommendations was the use of the cut and fill technique to solve the problem.

. Chronology

The design of the surface pillars was not based on either analytical calculations or on any geostructural study of the rock mass.

ORGANIZATION CHART - PILLARS DESIGN
ORGANIGRAMME - CONCEPTION DES PILIERS

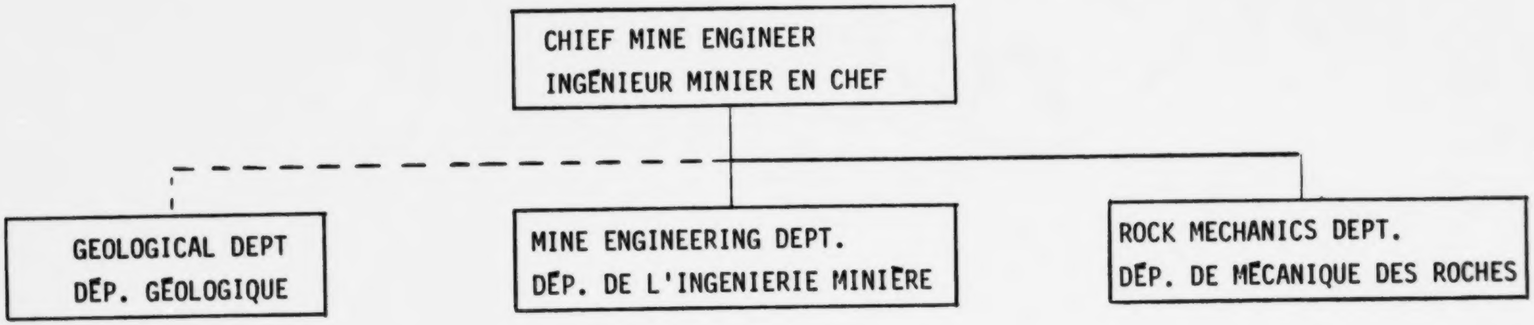
CHIEF MINE ENGINEER
INGÉNIEUR MINIER EN CHEF
GEOLOGICAL DEPT
DÉP. GÉOLOGIQUE
MINE ENGINEERING DEPT.
DÉP. DE L'INGENIERIE MINIÈRE
ROCK MECHANICS DEPT.
DÉP. DE MÉCANIQUE DES ROCHES

Figure 7.4

The contact point between the overburden and the rock was established by a series of test drills. The design of the surface pillars was influenced by the length and breadth of the veins near the surface and the thickness was arbitrarily set at 40 ft (12m). No later changes were made to the initial design of the surface pillars.

. Design Factors

The design criteria were based on a practical approach resulting from the experience of mining personnel with more than fifteen years in underground mines.

. Pillar Dimensions

The thickness of the pillars averages 35 feet (11 m) and the thickness/width ratio varies between 2.5 and 9.2. Table 7.2 gives a general view of the dimensions of surface pillars and underlying stopes.

DIMENSIONS OF SURFACE CROWN PILLARS

DIMENSIONS DES PILIERS DE SURFACE

TABLE 7.2
TABLEAU

DIMENSIONS		PILLARS - PILIERS							
		#1	#2	#3	#4	#5	#6	#7	#8
. THICKNESS: EPAISSEUR:									
- WATER BODY PLANS D'EAU	feet-pi. (m)	-	-	-	-	-	15 (5)	15 (5)	15 (5)
- OVERBURDEN MORTS-TERRAINS	feet-pi. (m)	6 (2)	20 (6)	30 (9)	15 (5)	20 (6)	15 (5)	15 (5)	15 (5)
. SURFACE CROWN PILLAR: PILIER DE SURFACE:									
- THICKNESS EPAISSEUR	feet-pi. (m)	20 (6)	25 (8)	30 (9)	40 (12)	15 (5)	45 (14)	50 (15)	55 (17)
- WIDTH LARGEUR	feet-pi. (m)	6 (2)	6 (2)	6 (2)	6 (2)	6 (2)	18 (5)	12 (4)	8 (2)
- LENGTH LONGUEUR	feet-pi. (m)	165 (50)	80 (24)	880 (268)	120 (37)	200 (61)	40 (12)	45 (14)	90 (27)
- THICKNESS/WIDTH RATIO RAPPORT EPAISSEUR/LARGEUR		3.3	4.2	5.0	6.7	2.5	2.5	4.2	6.9
. STOPE HEIGHT HAUTEUR DU CHANTIER	feet-pi. (m)	100 (30)	80 (24)	110 (34)	120 (37)	140 (43)	30 (9)	30 (9)	25 (8)
. FILL HEIGHT HAUTEUR DU REMBLAI	feet-pi. (m)	0	0	0	0	0	0	0	0

7.10 VISUAL EVALUATION OF THE SURFACE PILLAR(S)

The upper stopes were not filled after being worked. In the "NC" zone, the drawing points and the wooden ceilings of the drifts are still intact and the wooden beams set across the stopes appear to be well-preserved. Wall caving is not apparent. The rock walls show little fracturing; the R.Q.D. is estimated at 60 to 80%. No distinct joint system can be detected. Fractures are found in different locations and seem to follow no particular direction. No sizeable water infiltration can be seen; at most, the rock walls show surface dampness in some places. The stopes follow the geological layers. No bolts were used in the drift roofing.

The "NS" zone also shows fairly resistant rock. Ground conditions are similar to those in the "NC" zone except that more water is found (a slight water flow in some areas) and the rock mass seems more fractured. The R.Q.D. is estimated between 40 and 60%. The stopes visited in this zone do not have wooden structures such as observed the "NC" zone.

7.11 MANAGEMENT'S COMMENTS

No research program on surface pillars is currently in progress. However, management has expressed a desire to work certain surface pillars in a few years. The definition of the soil-rock contact remains their principal preoccupation. Rock quality seems consistently good and no major problem with water is foreseeable.

As to the future development of new underground mines, management is of the opinion that an approach based on structural geology and on geomechanical properties is highly desirable.

MINE #8

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8.0 SUMMARY OF THE VISIT

The copper-nickel ore is composed of massive sulfides and of breccia with sulfide inclusions along with banded greenstone and serpentine peridotite. The width of the deposit varies between 10 and 50 ft (3 and 15 m) over a distance of more than 6 200 ft (1,890 m). It is more or less continuous from east to west, sub-vertical and dips towards the east.

To the west, the upper portion of the mine reaches the contact point between the bedrock and the overburden. This zone lies beneath a lake about 25 ft (8 m) deep and under a layer of overburden as much as 150 ft (46 m) thick. Some survey work has been done to determine the composition and characteristics of the soil as well as to locate the underlying bedrock.

Mine walls are in general of low competence and have been influenced by a major fault to the south of the ore zone. Many secondary faults or fissures cut across the mine at a 60° angle and many slickensides are found in the modified peridotite.

Localized development drifts intercept water veins and grout has had to be used to control water infiltration. The mine pumps out about 800 (I) GPM (61 L/s) on a regular basis.

After several unsuccessful attempts using different mining techniques, the non-consolidated cut-and-fill method was adopted. Currently, the Company is converting its operations to the "VRM" method with consolidated fill. Thirty-foot (9 m) thick sill pillars are left every 150 vertical feet (46 m). No transverse pillars are left in the ore zone.

The present surface pillar is about 240 ft (73 m) thick, 2 800 ft (853 m) long and ranges from 10 to 50 ft (3 to 15 m) in width. No monitoring program has been established at this level.

The surface pillar has been established from criteria based on a general evaluation of the competence of the rock and of the presence of the surface lake.

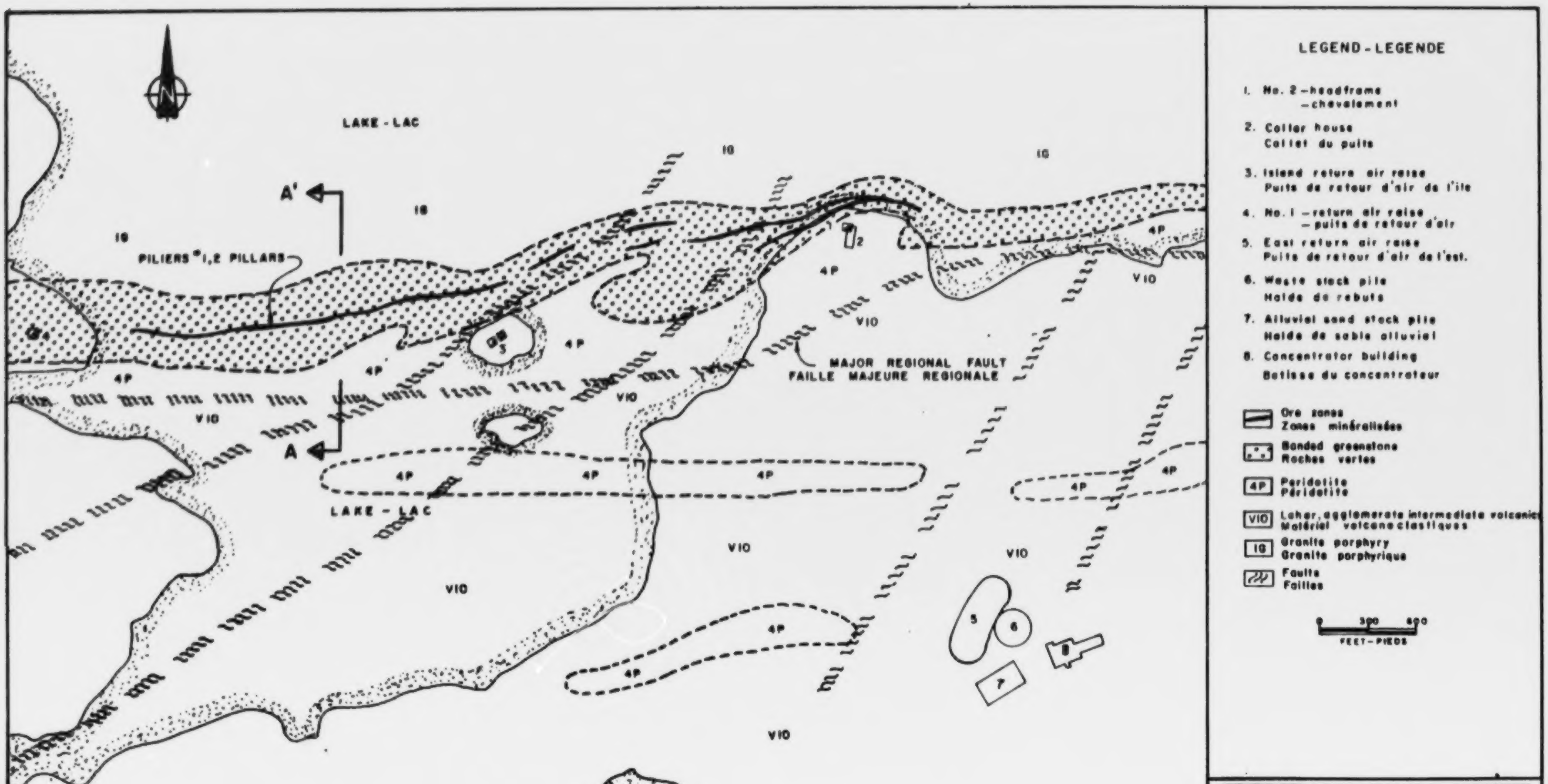
8.1 GENERAL INFORMATION

. Regional Geology

The property is located in the southern part of the geological Superior Province. The area is characterized by a wide band of metavolcanic rock and highly altered meta-sediments, generally striking east-west. The degree of metamorphism is that of green schist facies. This metavolcanic material is interspersed with intru- sive rock, mainly felsic. Also, on rare occasions, intrusions composed of mafic and ultra-mafic rock may be found. These generally form sills or linear inclusions within the sequence of the metavolcanic rocks.

. Local Geology

As shown in figures 8.1 and 8.2, the ore is linked with a band of serpentine peridotite or banded greenstone located near the contact point between the metavolcanic rocks (mainly composed of basalt) on the south side, and granite porphyry on the north side. The peridotite is greatly sheared and shows many smooth and striated surfaces caused by friction along the shearing planes. A major fault, also mentioned at the regional level, runs along the south part of the mine from east to west at a distance of 200 to 300 ft (61 to 91 m).


LAKE - LAC
IG
A'
A
PILIERS #1,2 PILLARS
4P
VIO
3
2
MAJOR REGIONAL FAULT
FAILLE MAJEURE REGIONALE
5
6
7
8
LEGEND - LEGENDE
1. No. 2 – headframe – chevalement
2. Collar house Collet du puits
3. Island return air raise Puits de retour d'air de l'ile
4. No. 1 – return air raise – puits de retour d'air
5. East return air raise Puits de retour d'air de l'est.
6. Waste stock pile Halde de rebuts
7. Alluvial sand stock pile Halde de sable alluvial
8. Concentrator building Batisse du concentrateur
Ore zones Zones minéralisées
Banded greenstone Roches vertes
4P Peridotite Péridotite
VIO Lahar, agglomerate intermediate volcanic Matériel volcanoclastiques
IG Granite porphyry Granite porphyrique
Faults Failles
0
300
600
FEET - PIEDS

ROCHE
associés ltée
Groupe conseil

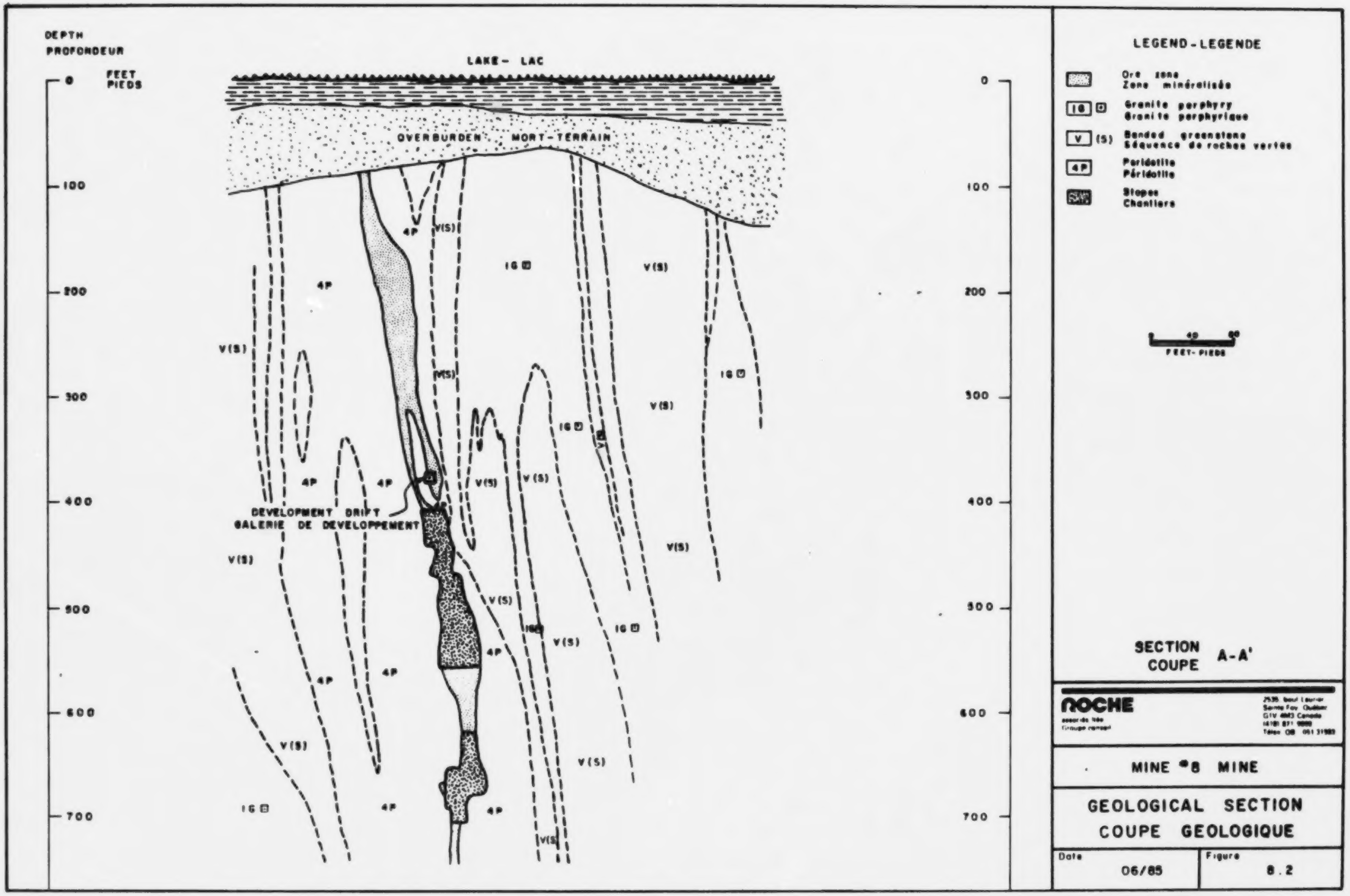
2535 boul Laurier
Sainte Foy, Québec
G1V 4M3 Canada
(418) 871 9600
Télex 05 051 31585

MINE #8 MINE

SURFACE PLAN
PLAN DE SURFACE

Date 06/85

Figure 8.1


DEPTH
PROFONDEUR
FEET
PIEDS
0
100
200
300
400
500
600
700
LAKE - LAC
OVERBURDEN MORT-TERRAIN
4P
V(S)
IG ▣
DEVELOPMENT DRIFT
GALERIE DE DEVELOPPEMENT
LEGEND - LEGENDE
Ore zone
Zone minéralisée
IG ▣ Granite porphyry
Granite porphyrique
V (S) Banded greenstone
Séquence de roches vertes
4P Peridotite
Péridotite
Stopes
Chantiers
0
40
80
FEET - PIEDS

SECTION A-A'
COUPE

ROCHE

MINE #8 MINE

GEOLOGICAL SECTION
COUPE GEOLOGIQUE

Date 06/85

Figure 8.2

. Characteristics of the Deposit

The metallic-type deposit is composed of a breccia of sulfurous ore and of massive sulfides. The ore is found in an intrusion of mafic and ultramafic rock (peridotite). The ores mined are copper and nickel in a ratio of about 0.5/1.0. The deposit is continuous along its longitudinal east-west axis but varies considerably in thickness. It is sub-vertical, leans at about 80° to the north and dips to the east.

The ore is, however, erratic along more than 6 200 ft (1,890 m) and for a thickness ranging from 10 to 50 ft (3 to 15 m). The eastern portion of the mine is made up of a ramified vein which tends to become single in the west section of the property. It comes to the surface in the sector where the surface pillar is discontinued.

Finally, the property has been in continuous operation since 1972 and produces around 1,500 t/day.

8.2 MINE ENVIRONMENT

As may be seen in Figure 8.1, the western portion of the property is completely covered by a lake. We therefore concentrated on the area between #1 shaft and the ventilation raise situated on the rocky island. In this area, the lakebed is composed of overburden between 100 and 150 ft thick (30 and 46 m).

A surface pillar was necessary in this area even though the ore reaches the soil-rock interface. Elsewhere on the property, since the upper layer of ore is located about 500 ft (152 m) below the interface, no mining will be conducted below this level. Consequently, the eastern zone has been omitted from this study.

8.3 OVERBURDEN

. Studies

A geotechnical study was conducted in the surface pillar zone or more precisely, between the ventilation and the #1 shaft on the lakeshore. As has been pointed out, the ore reaches the overburden-rock interface in this sector. The study had two purposes: to evaluate the rock profile and to gather indications on the stratigraphy of the lakebed.

The ultimate objective of the survey was to verify the existence of major depressions which might affect the thickness of the rock left as a surface pillar. The results of the study also permitted a preliminary feasability study for a project to mine this pillar by the open pit method after removal of the overburden. It was therefore necessary to know its composition, quantity, etc.

In this example, two sources of information were used by the Company:

i) diamond drilling used in the exploration of the property;

ii) special drilling for obtaining samples of the overburden. The position of this drilling is shown in figure 8.3.

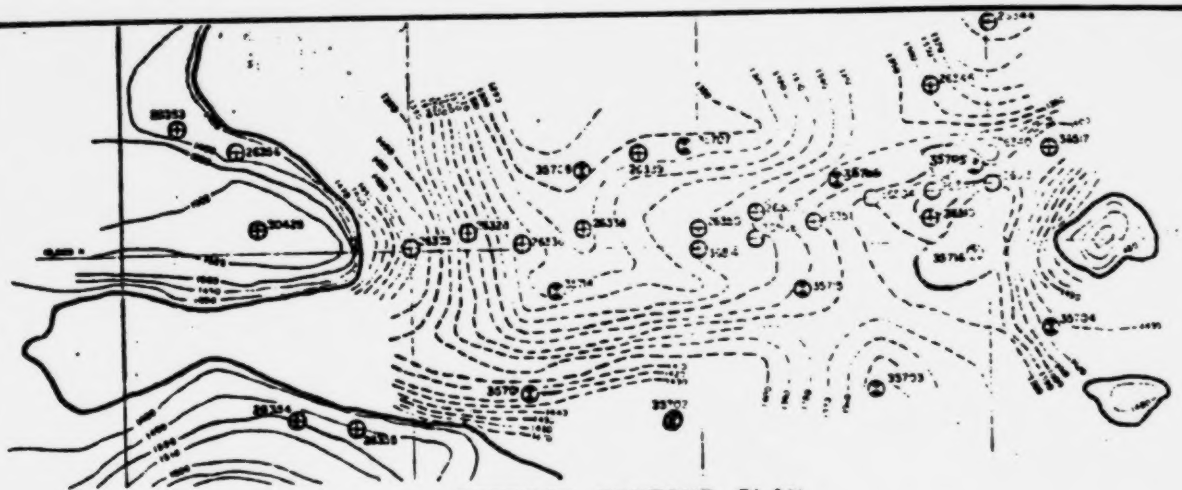
. Stratigraphy and Characteristics

First, the rock profile was determined on the mine's longitudinal axis (E-W) at intervals of approximately 200 ft (61 m). However, the values obtained should be interpreted with caution as most of the exploration drilling was done at an average angle of 50° off horizontal.

A series of 10 additionnal bores were ordered to take ground samples and to better define the rock profile. These drill holes were spread about the mine as far as about 400 ft (122 m) to the north side and 600 ft (183 m) to the south side in order to fill the blanks left by the exploration drilling. They were done vertically and 2 in (51 mm) samples were obtained.

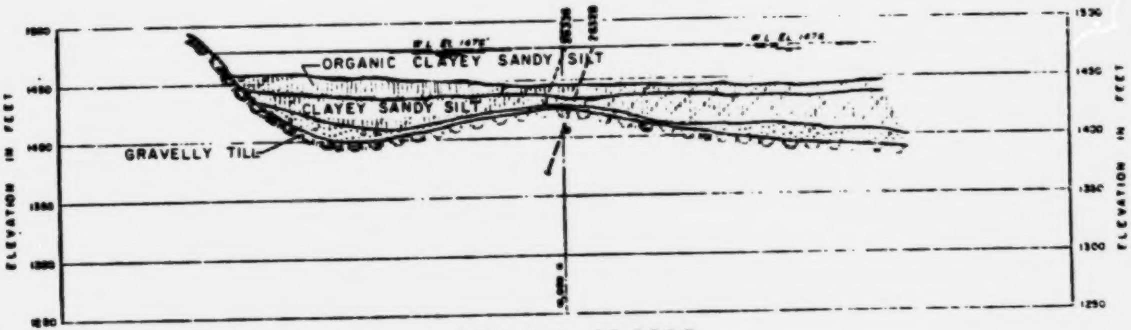
Unfortunately, it has been impossible to trace the results of analyses done on this material. We did, however, obtain samples of some vertical sections of material (Figure 8.3) and a brief description of these is compiled in Figure 8.4. Standard penetration tests or blow counts indicate that the density of the material increases with depth. We estimate the density of the ground material between 100 and 145 lbs/ft^3 (16-23 KN/m^3). There is no layer of hard clay or other sufficiently compact material to offer any real support.

These types of materials are of course 100% saturated and likely to be free flowing if not retained by the underlying bedrock. No attempt has been made by the Company to modify the conditions of the overburden since the beginning of mining operations.

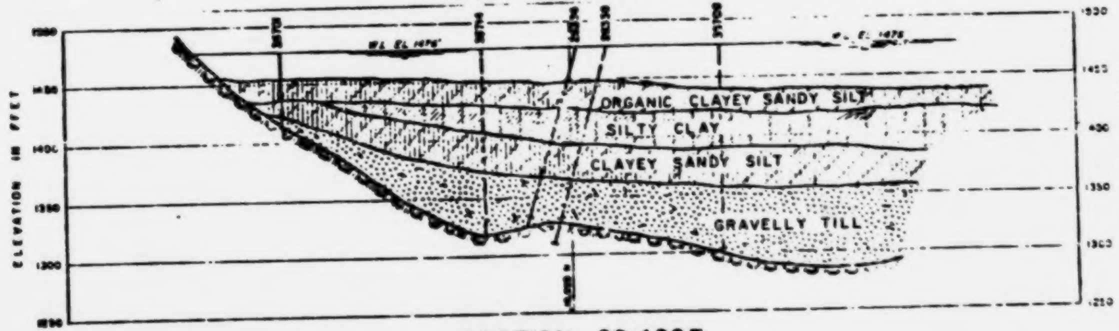

35702
35705
35716
35734
35733
35707
35703
30425

BEDROCK CONTOUR PLAN

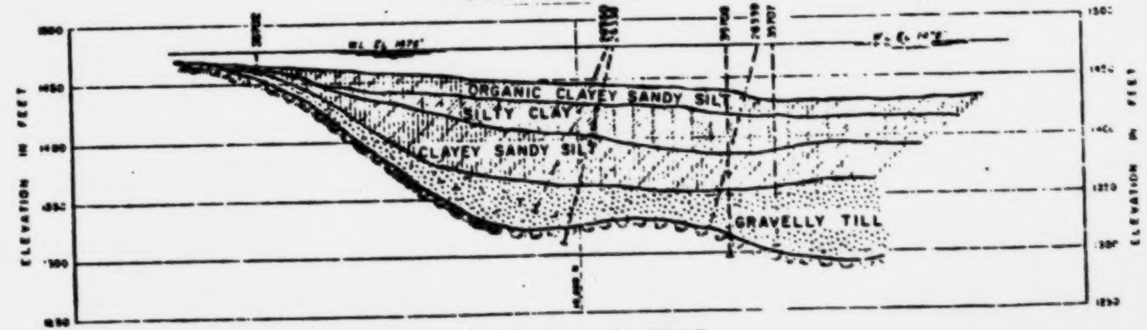
SCALE 0
500
1000 FEET


W.L. EL 1476'
ORGANIC CLAYEY SANDY SILT
CLAYEY SANDY SILT
GRAVELLY TILL
ELEVATION IN FEET
1500
1450
1400
1350
1300
1250

SECTION 20,000E


W.L. EL 1476'
ORGANIC CLAYEY SANDY SILT
SILTY CLAY
CLAYEY SANDY SILT
GRAVELLY TILL
ELEVATION IN FEET
1500
1450
1400
1350
1300
1250

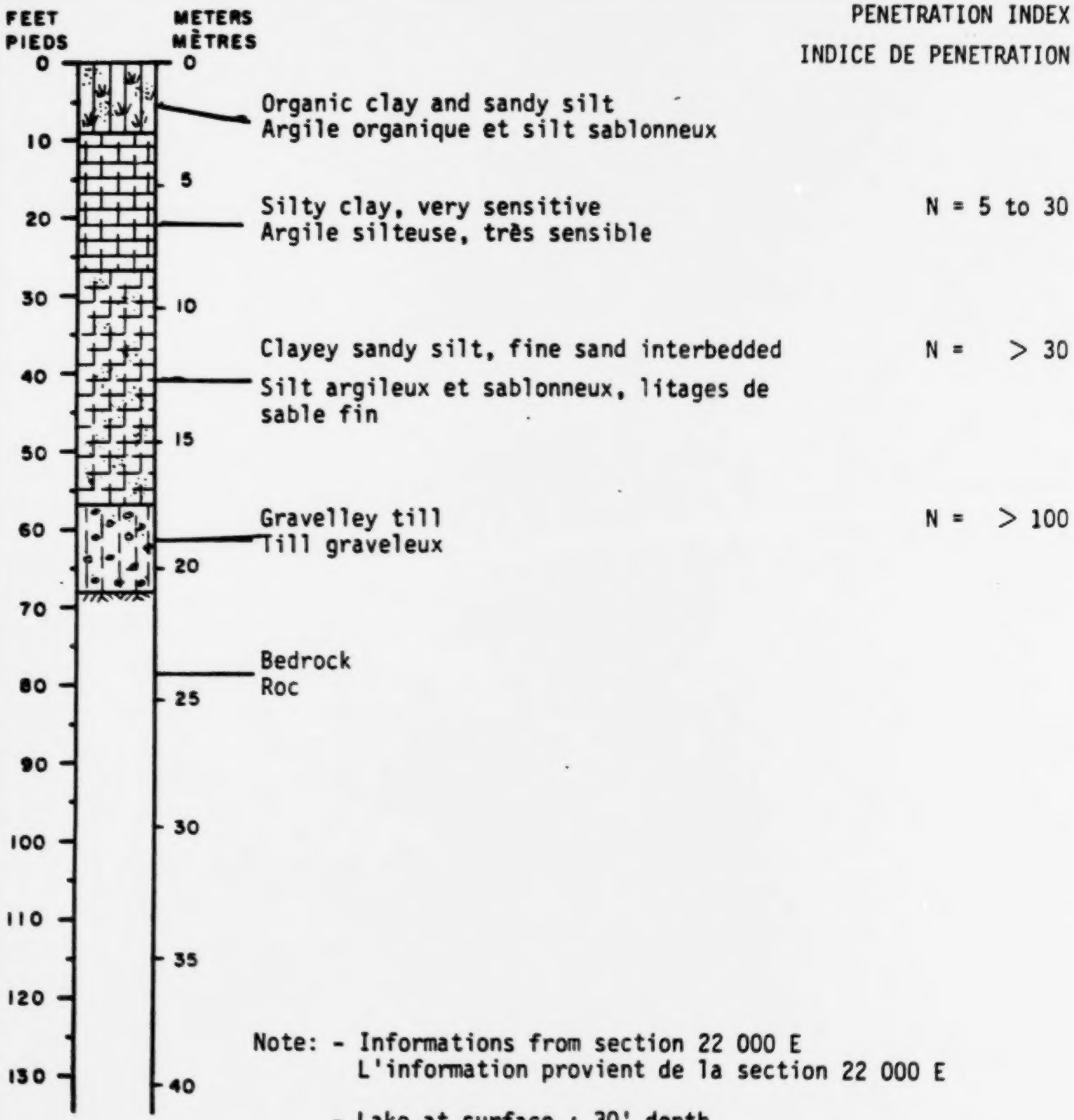
SECTION 20,400E


W.L. EL 1476'
ORGANIC CLAYEY SANDY SILT
SILTY CLAY
CLAYEY SANDY SILT
GRAVELLY TILL
ELEVATION IN FEET
1500
1450
1400
1350
1300
1250

SECTION 20,800E

FIG. 8.3 : POSITION OF DRILLING
POSITION DES FORAGES

SOIL STRATIGRAPHY
STRATIGRAPHIE DU SOL


FEET
PIEDS
METERS
MÈTRES
0
10
20
30
40
50
60
70
80
90
100
110
120
130
0
5
10
15
20
25
30
35
40
PENETRATION INDEX
INDICE DE PENETRATION
Organic clay and sandy silt
Argile organique et silt sablonneux
Silty clay, very sensitive
Argile silteuse, très sensible
N = 5 to 30
Clayey sandy silt, fine sand interbedded
Silt argileux et sablonneux, litages de sable fin
N = > 30
Gravelley till
Till graveleux
N = > 100
Bedrock
Roc

Note: - Informations from section 22 000 E
L'information provient de la section 22 000 E

- Lake at surface : 30' depth
Lac en surface : 30' de profondeur

		Date	Figure
ROCHE associés ltée Groupe-conseil 2535, boul Laurier, Sainte-Foy, Québec G1V 4M3 Canada (418) 871 9800 Télex OBC 051 31583	MINE # 8 MINE	07-1985	8.4

8.4 ROCK MASS

. Nature of the Rock

The immediate footwall is of peridotite with inclusions of sub-volcanic rock or granite porphyry. The hanging wall is a mixture of peridotite and larger incusions of granite porphyry alternating with bands of greenstone namely andesite and basalt. The mine is mainly a massive sulfide; except for the degree of metamorphism, it is difficult to evaluate whether the upper portion of the mine has been chemically altered by water. The Company has no shaft inside the surface pillar zone.

. Structural Geology

The most important structure is the main fault located about 300 ft (90 m) south of the deposit. Though of later origin than the mineralization, it has a definite influence on the present structure of the ore zone. In conjunction with this fault, a relatively extensive secondary fracture network must be taken into account. These secondary faults cut across the main axis of the mine at a 60° angle and plunge towards the west at about 75°; they are spaced between 5 and 10 ft (1.5 to 3 m) apart. Figure 8.5 gives a schematic illustration of this phenomenon.

Some major faults cut across the mine at an angle of 60° in relation to its main axis but are located outside the surface pillar zone (see Figure 8.1).

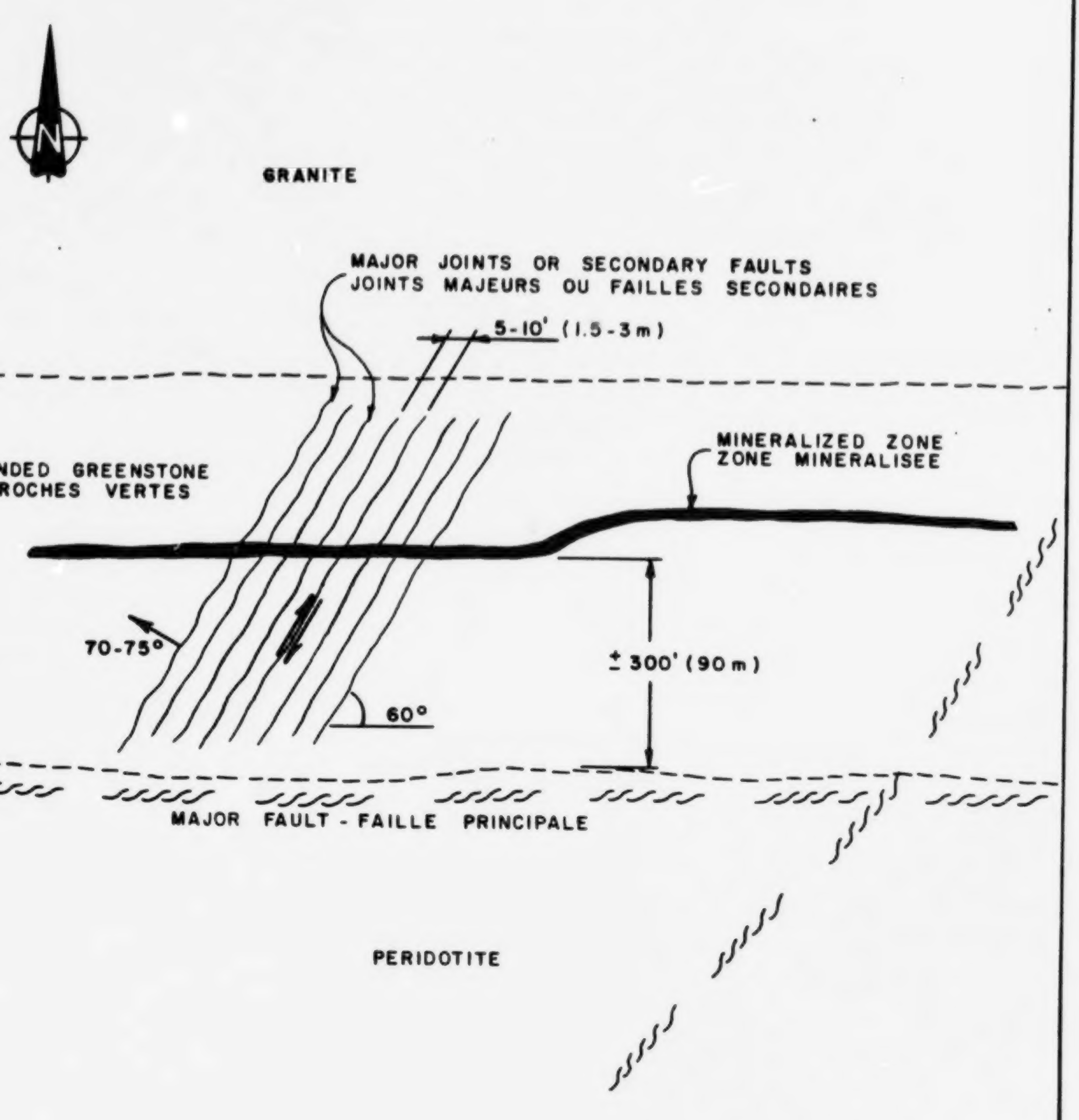

GRANITE
MAJOR JOINTS OR SECONDARY FAULTS
JOINTS MAJEURS OU FAILLES SECONDAIRES
5-10' (1.5-3 m)
MINERALIZED ZONE
ZONE MINERALISEE
BANDED GREENSTONE
ROCHES VERTES
70-75°
± 300' (90 m)
60°
MAJOR FAULT - FAILLE PRINCIPALE
PERIDOTITE

FIG. 8.5 STRUCTURAL FEATURES
SYSTEME DE FAILLES

Overall the peridotite shows well-defined lineation parallel to the dip of the orebody (80° N) with numerous slickensides.

. Characteristics

The Company has not determined the geomechanical properties of the rocks characteristic of the mine. However, all personnel interviewed were unanimous in describing the quality of the rocks as follows:

> "The mine is very competent though
> the rock walls are soft".

The only quantitative values obtained on the visit concerned the density of the materials:

peridotite	:	2.90
granite porphyry	:	2.75
massive sulfides	:	3.44

The rock mass has not been classified according to R.Q.D. measurements or using any of the other numerous classifications.

In both footwalls and hanging walls, contact points between the mine and the host rock are very distinct and show a definite strike and dip orientation. These planes, joined at major points as discussed earlier, create serious stability problems.

As numeric values on the quality of the rock mass are unavailable, an appreciation was arrived at by studying the evolution over time of the mining techniques used in this mine. This is discussed in chapter 6 of this text.

8.5 HYDROGEOLOGICAL CONDITIONS

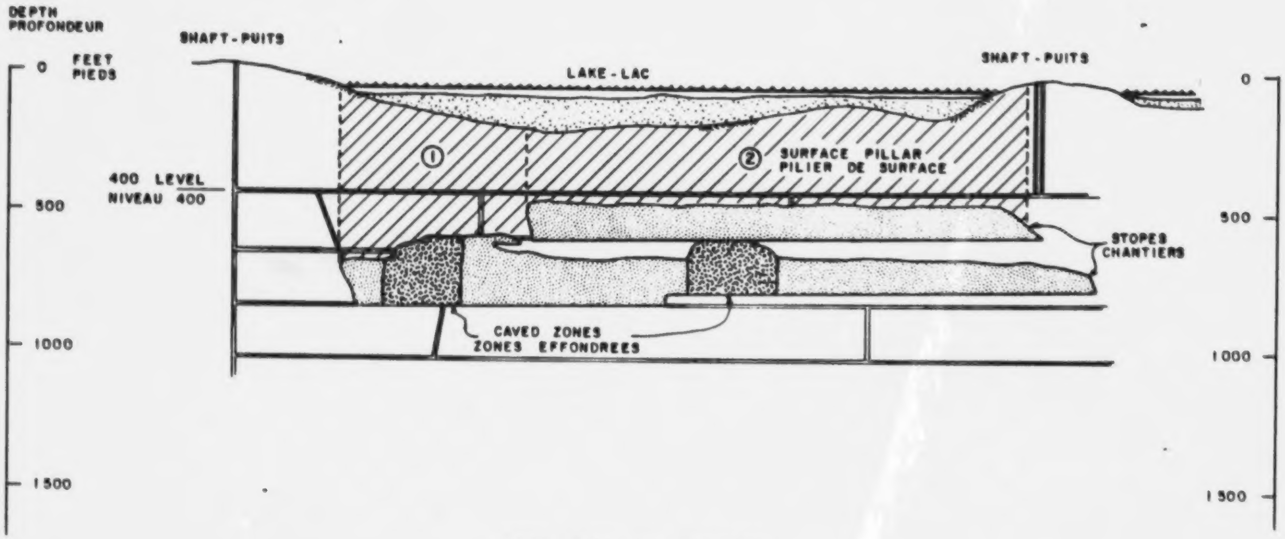
. Overburden

The entire western portion of this operation is located beneath a lake. The overburden at the lakebed is definitely 100% saturated. It is not, however, known whether aquifers in any quantity exist in this zone.

. Rock Mass

When they were opening the drift at level 400 (see Figure 8.6), the operators ran into several water veins generally associated with major transversal faults. These veins created some short term problems, but should not create any serious water intake difficulties in the future. Since drift 400 follows the mine's longitudinal axis right through its western portion, the limited success of attempts at plugging through the use of shotcrete would appear indicative of the high degree of fracturing in the walls (composed of peridotite). In fact it was reported that shotcrete did not succeed in stopping water infiltration but rather displaced it from one site to another. On the other hand, plugging done at the time the shafts were dug was much more successful.

The pumping installations are conventional and the mine evacuates about 800 (I) GPM (61 L/s) on an annual basis with no noticeable seasonal variation.


DEPTH
PROFONDEUR
FEET
PIEDS
0
500
1000
1500
SHAFT - PUITS
LAKE - LAC
SHAFT - PUITS
400 LEVEL
NIVEAU 400
①
②
SURFACE PILLAR
PILIER DE SURFACE
STOPES
CHANTIERS
CAVED ZONES
ZONES EFFONDREES
0
500
1000
1 500

WEST SIDE OF OREBODY
SECTEUR OUEST DE LA MINE

LEGEND - LEGENDE

0 200 400
FEET - PIEDS

ROCHE
associés ltée
Groupe-conseil

2535 boul Laurier
Sainte-Foy Québec
G1V 4M3 Canada
(418) 871 [illegible]
Telex [illegible]

MINE #8 MINE

LONGITUDINAL SECTION
COUPE LONGITUDINALE

Date 08/85
Figure 8.6

8.6 MINING OPERATIONS

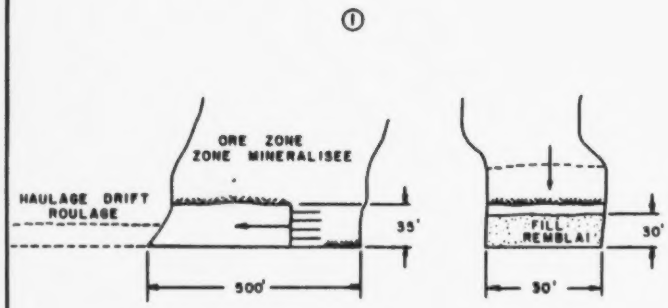
As previously mentioned, the best approach to an appreciation of the quality of the rock mass seems to be through a study of the evolution of the mining techniques.

. Mining Methods

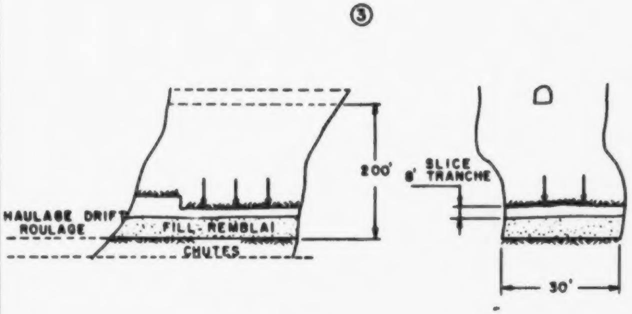
Figure 8.7 gives a very schematic illustration of the sequence of methods used. In all, the Company has used four (4) different mining methods, described hereafter in chronological order. Currently methods #3 and #4 are in use but progressively only the latter will be retained. In most cases, stopes are 500 ft (152 m) long and an average of 30 ft (9 m) wide.

Method #1 was used in only one "pilot" stope. This is called the block cut-and-fill method and consists of drilling horizontally and blasting out a 35 ft (10.6 m) high trench throughout the length and width of the stope. Once the ore is removed, only 30 ft (9 m) of uncemented hydraulic fill is placed in the stope. This is done progressively working from the bottom to the top. The stope was mined with difficulty to a height of 200 ft (61 m) when a major cave-in put an end to its exploitation. The method did not allow for adequate support.

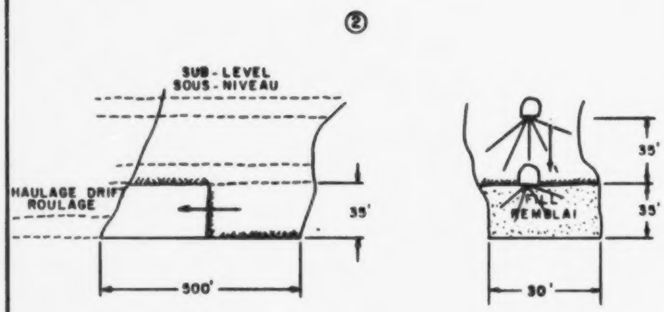
Technique #2 is a modified version of the first. The ore is recovered through long holes drilled from sub-levels located at the center of the stope and spaced at a height of 35 ft (10.6 m).


①
ORE ZONE
ZONE MINERALISEE
HAULAGE DRIFT
ROULAGE
35'
500'
FILL
REMBLAI
30'
30'

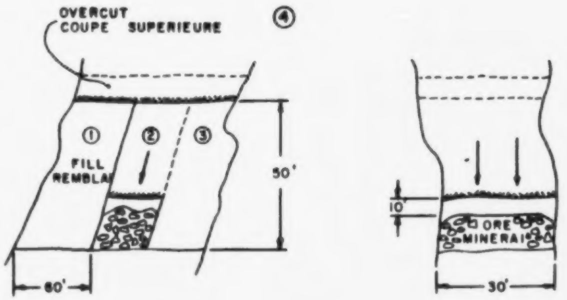
BLOCK CUT-AND-FILL
CHAMBRE ET REMBLAI PAR BLOCS


③
HAULAGE DRIFT
ROULAGE
FILL-REMBLAI
CHUTES
200'
SLICE
8' TRANCHE
30'

MECHANIZED CUT-AND-FILL
CHAMBRE ET REMBLAI MECANISE


②
SUB-LEVEL
SOUS-NIVEAU
HAULAGE DRIFT
ROULAGE
35'
500'
35'
35'
FILL
REMBLAI
30'

MODIFIED BLOCK CUT-AND-FILL
CHAMBRE ET REMBLAI PAR BLOCS (MODIFIEE)


OVERCUT
COUPE SUPERIEURE
④
①
②
③
FILL
REMBLAI
50'
60'
10'
ORE
MINERAI
30'

"V.R.M." METHOD
METHODE "V.R.M."

LEGEND - LEGENDE

ROCHE

MINE # 8 MINE

MINING METHODS
METHODES DE MINAGE

Date 08/85
Figure 8.7

Stopes where this method was used are 100, 200 and 300 ft long (30, 61 and 91 m). Here again the stopes were filled after removal of the ore. This method produced excessive dilution from the stope walls and it was stopped after three (3) cave-ins. Here again, inadequate support was the cause of the failures.

Technique #3 is the classic mechanized cut-and-fill method. Equipment is captive in the stopes and trenches 8 ft (2.4 m) thick are drilled and blasted upwards from the bottom to a height of 200 ft (61 m). Uncemented hydraulic fill is used here as well. No cave-in occurred with this technique and dilution from the walls was minimal.

Technique #4 is the "VRM" or "vertical retreat mining" method which is becoming more and more popular in operations of mass extraction. It is mainly used in the eastern part of the mine but will soon become prevalent over the whole property. It is done by drilling 6½ in (165 mm) holes from sub-levels spaced at 50 ft (15 m) in height. The stope is mined in longitudinal sections 60 ft (18 m) long and equal to the width of the ore zone, an average of 30 ft (9m). The empty space 60 x 30 x 50 ft (18 x 9 x 15 m) in height is then filled with consolidated fill before the blasting of the next section. This technique produces good results in terms of ground support but management believes that the blasting causes a certain amount of dilution. No cave-in occurred using this technique.

. Operating Conditions

From Figure 8.6 it may be seen that the percentage of ore extraction is about 80%. No transverse pillars are left between the stopes along the longitudinal axis of the ore zone. Sill pillars, however, have been left every 150 vertical ft (46 m). Overall, the deposit is mined from top to bottom, but individual stopes are worked from bottom to top.

According to the operators, blasting is an important element in stability control on this property. With the "VRM" technique, the Company uses the following blasting parameters:

- powder factor : 1.0 - 1.5 lbs/t (0.4-0.7 kg/t)
- drill hole : 6½ in Ø (165 mm Ø)
- drilling pattern : 10 ft x 10ft (3 x 3 m)
- drilling sequence : 150 lbs max/delay (68 kg)

With the "VRM" technique, the average time for filling after the final drawing of the stope is about one (1) month. In the area of the western surface pillar where the cut-and-fill method was used, filling time was about the same for a trench 7 ft (2 m) thick, 30 ft (9 m) wide and 400-500 ft (122-152 m) long.

8.7 SUPPORT AND REINFORCEMENT METHODS

. Primary Support

The general stability of the mine is achieved by leaving sill pillars 30 ft (9 m) thick every 150 vertical ft (46 m). No transverse pillars have been left between the stopes. Thus, in the western portion of the mine more than 2 800 ft (853 m) have been opened without the use of rib pillars (see Figure 8.6).

. Filling and Reinforcement

Since the start of its operations, the Company has been using conventional bolts 6 or 8 ft long (1.8 or 2.4 m) according to terrain conditions. There is no fixed standard since the purpose of the bolting is to prevent falling rock. Since the introduction of the "VRM" method, the operators have been using swellex bolts on a 4 x 4 ft (1.2 x 1.2 m) pattern in the top sill. They judge these bolts to be more resistant to the vibrations caused by repeated blasting. In places where the peridotite is especially sheared, operators use bolts 16 to 21 ft long (4.9 to 6.4 m) or 16 ft (4.9 m) swellex bolts.

In general, uncemented hydraulic fill made up of classified tailings is used in the stopes. The haulage rate of the pulp is 300 (I) GPM (23 L/s). This type of fill is used in all stopes mined by the cut-and-fill technique.

In the stopes worked by "VRM", consolidated fill, 65% solid and composed of classified tailings and sand in a respective weight ratio of 60/40 is used. The bottom of the stope is filled with a cement/fill mixture in a ratio of 1:10, the rest of the stope in a 1:30 ratio.

This system of filling has a capacity of 1 000 (I)GMP (76 L/s). The Company uses conventional draining towers to remove water from stopes mined with the cut-and-fill technique and a drainage network for VRM stopes.

The characteristics of the consolidated fill are as follows:

density	: 3.02
compressive strength (1:10)	: 90 psi (0.62 MPa)
compressive strength (1:30)	: 20 psi (0.14 MPa)

No values were available for the unconsolidated fill.

Finally, it should be noted that the Company systematically monitors the torque on 10% of the conventional bolts installed and does traction tests on 10% of the swellex-type bolts as well. The results of these tests show values of 11 tons or more.

8.8 MONITORING PROGRAM(S)

. Stress Measurement

No stress measurement was taken at this mine.

. Displacement Measurement

Up to now, no measurement has been done. The Company intends, however, to equip some stopes in the lower parts of the mine with the appropriate instruments.

. Other Programs

The overall stability of the surface pillar may be evaluated by a survey of its base at the 400 level drift. No regular inspection is scheduled in this sector but several work crews use the drift and can therefore monitor conditions periodically.

8.9 SURFACE PILLAR DESIGN

. Personnel Involved

Figure 8.8 indicates all the personnel involved in the decision-making process surrounding the design of an element as important as the surface pillar.

. Chronology

Surface pillar dimensions have not been changed since the start of operations.

. Design Factors

The decision to set the upper level of mining at 400 ft (122 m) below the surface (leaving a minimal pillar of 240 ft: 73 m beneath the lake) was based on an approach that was both conservative and safety-minded. We could not trace any studies or internal memos on these precise subjects but the Company did possess widespread experience in the mining of other properties. Discussion with present personnel indicates that the poor quality of the peridotite was recognized very early and, as no precise data was available on the behaviour of the terrain, management preferred to retain a sizeable surface pillar.

At the moment, economic conditions are such that making the necessary effort to mine this zone in part or in its entirety is unattractive.

ORGANIZATION CHART - PILLARS DESIGN
ORGANIGRAMME - CONCEPTION DES PILIERS

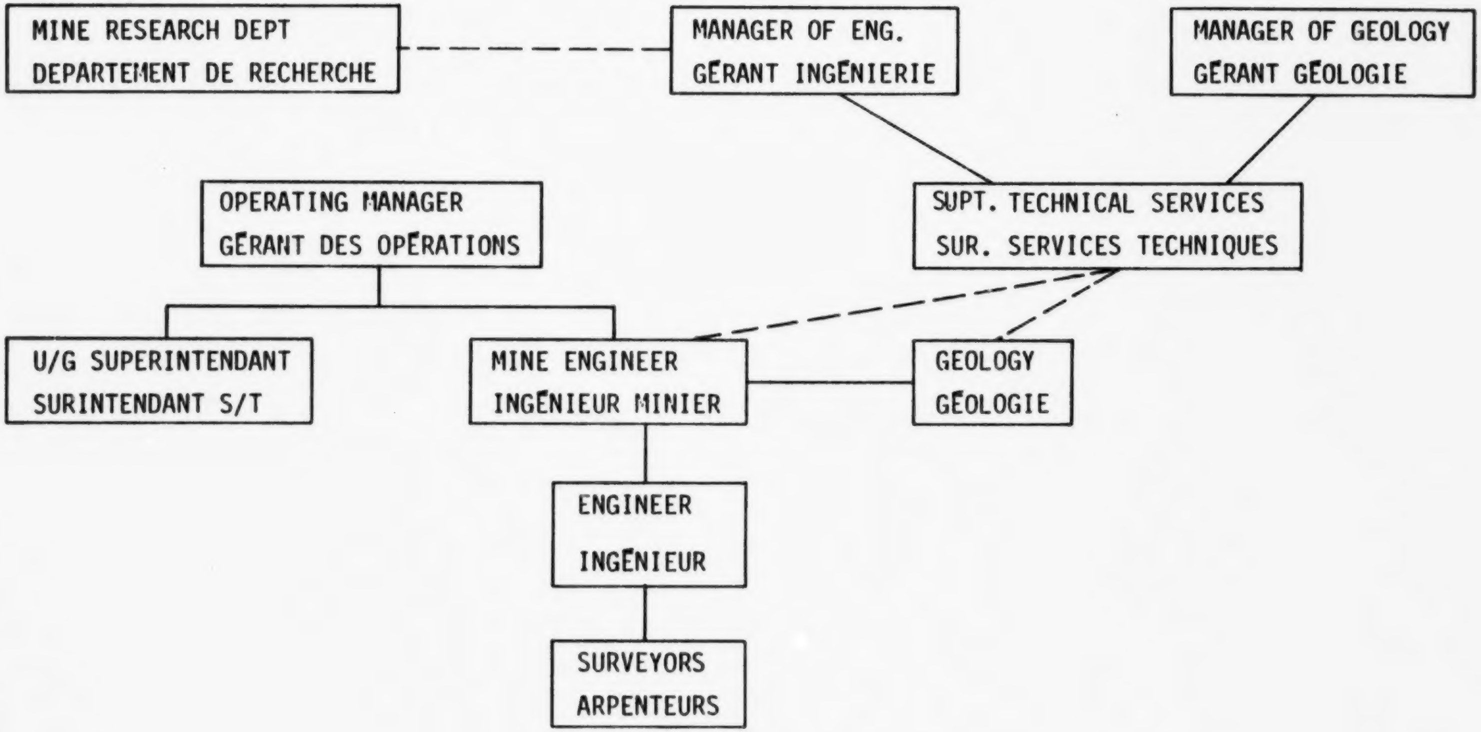

MINE RESEARCH DEPT
DEPARTEMENT DE RECHERCHE
MANAGER OF ENG.
GÉRANT INGÉNIERIE
MANAGER OF GEOLOGY
GÉRANT GÉOLOGIE
OPERATING MANAGER
GÉRANT DES OPÉRATIONS
SUPT. TECHNICAL SERVICES
SUR. SERVICES TECHNIQUES
U/G SUPERINTENDANT
SURINTENDANT S/T
MINE ENGINEER
INGÉNIEUR MINIER
GEOLOGY
GÉOLOGIE
ENGINEER
INGÉNIEUR
SURVEYORS
ARPENTEURS

Figure 8.8

. Pillar Dimensions

The surface pillar in the western sector of this mine may be divided in two parts as shown in Figure 8.6. In Table 8.1, minimal values were used for the thickness of the pillar and maximum values for the stope widths so as to obtain a variation in the height/width ratio.

DIMENSIONS OF SURFACE CROWN PILLARS

DIMENSIONS DES PILIERS DE SURFACE

TABLE 8.1
TABLEAU 8.1

DIMENSIONS		PILLARS - PILIERS							
		#1	#2						
. THICKNESS: EPAISSEUR:									
- WATER BODY PLANS D'EAU	feet-pi. (m)	25 (7,6)	25 (7,6)						
- OVERBURDEN MORTS-TERRAINS	feet-pi. (m)	0-110 (0-34)	40-110 (12-34)						
. SURFACE CROWN PILLAR: PILIER DE SURFACE:									
- THICKNESS (MIN.) EPAISSEUR	feet-pi. (m)	380 (116)	240 (73)						
- WIDTH (MAX.) LARGEUR	feet-pi. (m)	50 (15)	50 (15)						
- LENGTH LONGUEUR	feet-pi. (m)	690 (210)	1780 (542)						
- THICKNESS/WIDTH RATIO RAPPORT EPAISSEUR/LARGEUR		7.6	4.8						
. STOPE HEIGHT HAUTEUR DU CHANTIER	feet-pi. (m)	250 (76)	140 (43)						
. FILL HEIGHT HAUTEUR DU REMBLAI	feet-pi. (m)	250 (76)	140 (43)						

8.10 VISUAL EVALUATION OF SURFACE PILLAR(S)

The filled roof of the upper stopes of the mine is no longer accessible so we inspected the 400 level drift located immediately below (± 25 ft or 7.6 m) as shown in Figure 8.2.

This drift crosses all the formations described in the chapter on geology. Thus the quality of the bedrock varies from very good (RQD = 80%) to poor (RQD = 40%). There are no signs of important tectonic stress fields in this sector. The bedrock is sufficiently fractured to assume that stability is related to structural control.

Locally, some running water is present along the eroded fractures within the peridotite. The ore zone is more competent than the walls and no signs of subsidence are visible in the drift.

The fill plays a vital role in this operation as it prevents scaling of the less competent walls thus avoiding a progressive deterioration of the stope walls.

8.11 MANAGEMENT'S COMMENTS

Management is much more concerned about the presence of water than about the possibility of a rock cave-in, although the two are related.

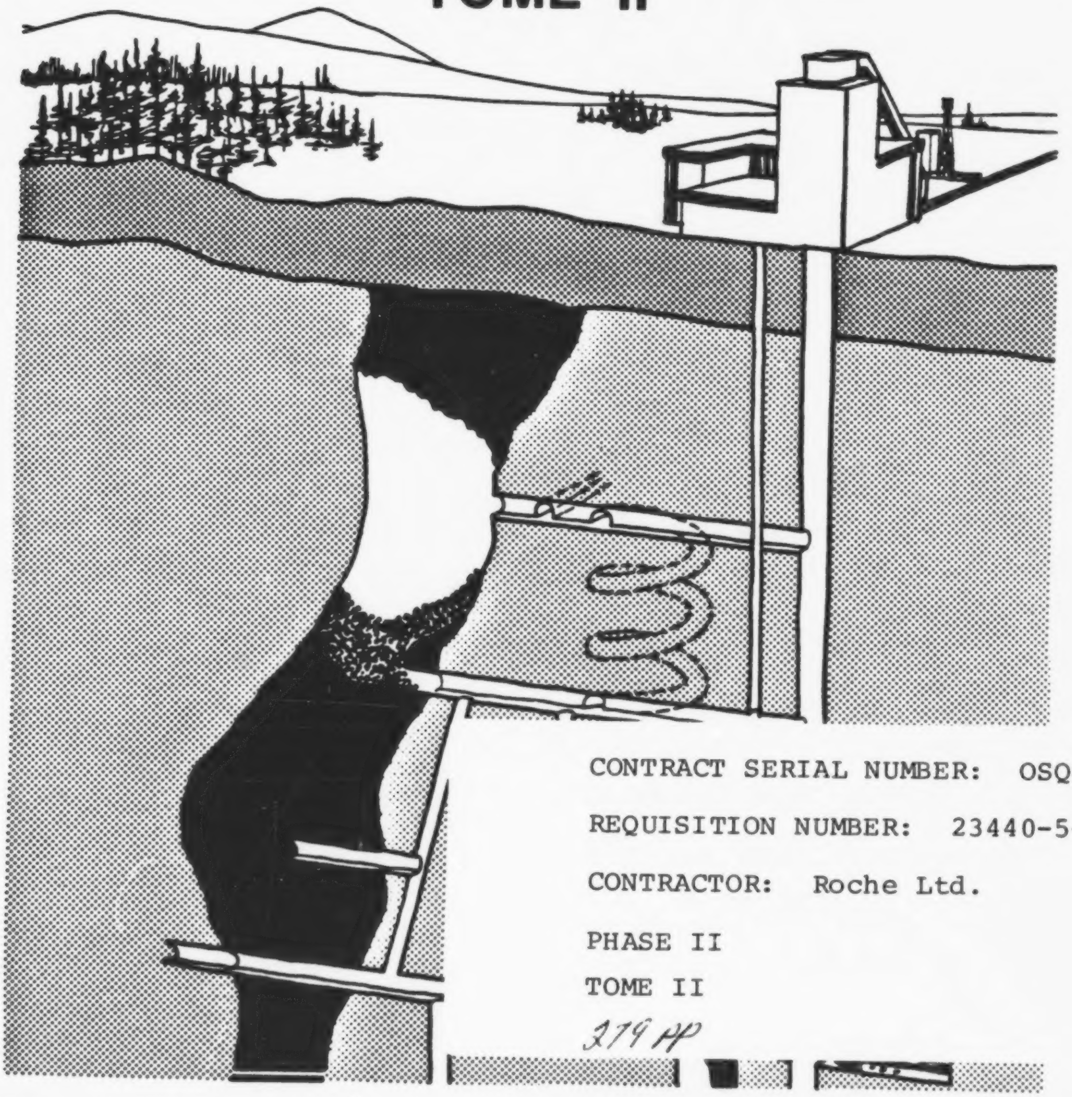
They say that the engineers are poorly equipped, lacking such tools as case histories. The notion of risk would be worth developing; what is an acceptable risk for an operator in an underground mine? They would like to work within measured safety factors. As it is, it is known that the pillar, at 240 ft (73 m) is perfectly stable but its optimum thickness remains undetermined.

Energy, Mines and Resources Canada
Research and Technology

Énergie, Mines et Ressources Canada
Recherche et Technologie

SURFACE PILLARS - PHASE II

TOME II



CONTRACT SERIAL NUMBER: OSQ85-00003

REQUISITION NUMBER: 23440-5-9014

CONTRACTOR: Roche Ltd.

PHASE II

TOME II

379 pp

ROCHE MINES
Ltée Groupe-conseil

FINAL REPORT

AUG 15 1986
MICROMEDIA

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TOME II

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MINE #9

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9.0 SUMMARY OF THE VISIT

Although this property did not provide many quantitative details with regards to surface pillar design, it is located in an interesting area from a geological and a mining point of view. At the surface in the western sector of the property, the ore is of the lense type while in the eastern sector it is more like an ore mass.

The deposit slopes at 40-45° beneath a marshy zone containing an aquifer of relatively weak capacity situated at the rock interface. A layer of impermeable clay, located above the aquifer, limits the infiltration of surface water and minimizes its effects on the operation.

The upper stopes of the mine have been worked without problem for more than 50 years. After being mined using the shrinkage stoping method, the stopes were left open for several years before being filled with either a sand-gravel mixture or with rock. General stability was maintained by leaving 40 foot (12 m) thick rib pillars at intervals of about 100 ft (30 m).

No surface pillar design as such was made as production reached the upper limit of the ore leaving pillars ranging between 55 and 325 ft thick (16.5 to 98 m).

The operators interviewed report no signs of surface subsidence nor of deterioration of the rib pillars in the upper portion of the mine. In this part of the deposit, extraction of the pillars has only just begun whereas the recuperation of the pillars is well underway elsewhere. This case will be interesting to monitor in the near future.

9.1 GENERAL INFORMATION

. Regional geology

The property is located on the north bank of the Sudbury basin. Formations generally strike N-E and dip at about 40° towards the center of the basin. Except for the many formations in the center, three layers of igneous rock ring the basin and are known collectively as the Sudbury igneous complex. This band of rock about 2.4 mi (4 km) thick is subdivided starting at the center and working out, as follows:

Upper zone	: 1.7 mi (2.8 km) granophyre
Intermediate zone	: .36 mi (0.6 km) quartz gabbro
Lower zone	: .36 mi (0.6 km) felsic and mafic norite

Tectonic effects are apparent throughout this band of volcanic rocks. Several major faults have been mapped both at a regional and local scale and numerous studies discuss the deformation mechanisms involved. Figure 9.1 is a sketch map of the area just described. The reader seeking more information on the geological structure of the Sudbury basin may consult the following reference material:

> "The Geology and ore deposits of the Sudbury structure"
> Ontario Geological Survey, Special volume 1
> ISBN 0-7743-9423-4
> 1984

which describes both the geology and the structure of this basin in detail.

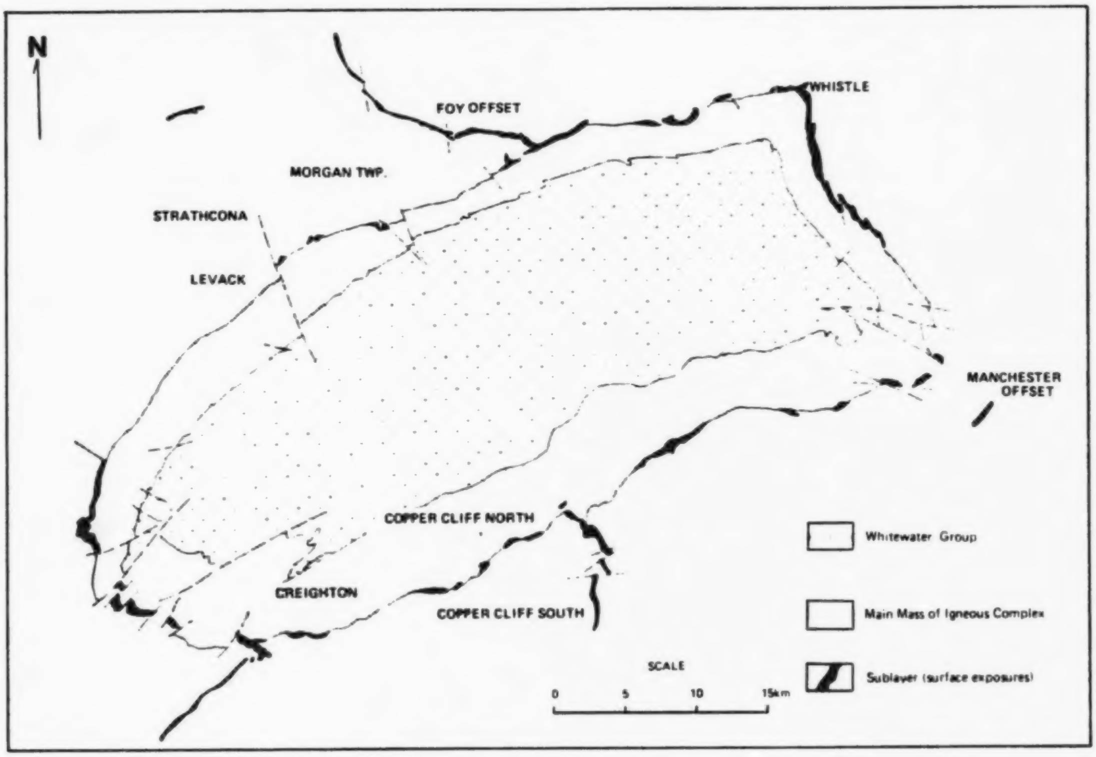

N
FOY OFFSET
WHISTLE
MORGAN TWP.
STRATHCONA
LEVACK
MANCHESTER OFFSET
COPPER CLIFF NORTH
CREIGHTON
COPPER CLIFF SOUTH
Whitewater Group
Main Mass of Igneous Complex
Sublayer (surface exposures)
SCALE
0
5
10
15km

Fig. 9 .1 Sketch map of the Sudbury igneous complex showing the distribution of the contact sublayer.

Carte du complexe igné de Sudbury illustrant la distribution des contacts des couches inférieures.

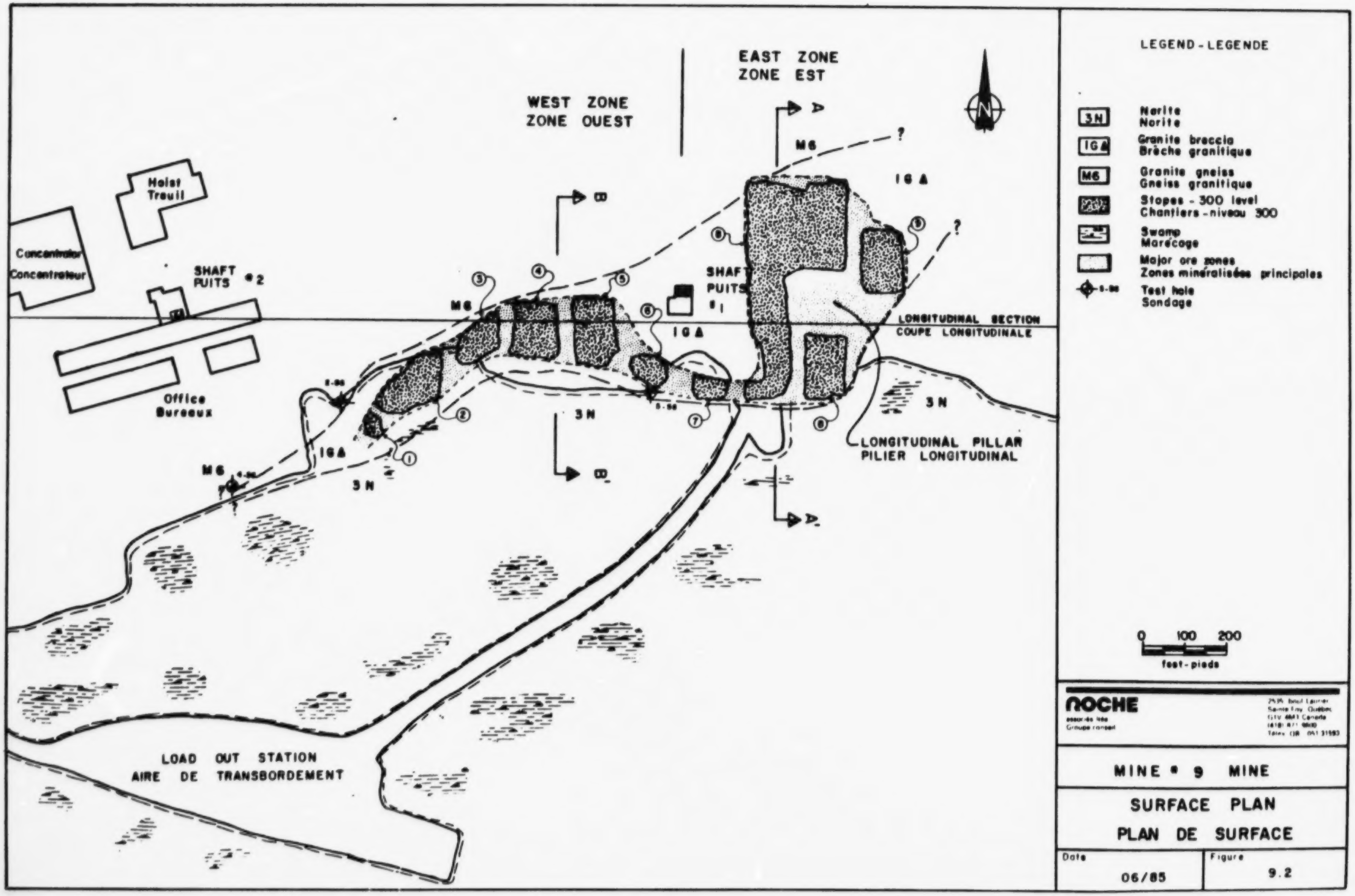
. Local geology

As shown in figures 9.2, 9.3 and 9.4, the mine is located at the contact between the lower portion of the Sudbury Basin complex (composed of norite) and the regional units composed of Archean igneous rocks.

In the immediate vicinity of the property, the footwall is made up of a granitic gneiss under a granitic breccia containing ore while the hanging wall is composed of norite.

A major shearing zone, though it does not cover all the upper levels of the mine, crosses the norite at a distance of between 0 and 150 ft (0 and 45 m) from the breccia/norite interface. This zone should be retained as an important element when considering the stability of the underground excavations.

Lastly, it may be noted that the units of footwall have been subjected to metamorphism from contact with a halo effect reaching as much as .6 mi (1 km). It is recognized that in the area of the property under study, the zones of granite breccia are known for their high degree of metamorphism and are thus situated in contact with the norite. On the other hand, in the same area, outisde the breccia zone, the footwall is less irregular than elsewhere around the basin. The rock shows evidence of late granitization.


WEST ZONE
ZONE OUEST
EAST ZONE
ZONE EST
A
A'
B
B'
Hoist
Treuil
Concentrator
Concentrateur
SHAFT
PUITS #2
Office
Bureaux
SHAFT
PUITS
#1
M6
IGA
3N
①
②
③
④
⑤
⑥
⑦
⑧
⑨
⑩
?
LONGITUDINAL SECTION
COUPE LONGITUDINALE
LONGITUDINAL PILLAR
PILIER LONGITUDINAL
LOAD OUT STATION
AIRE DE TRANSBORDEMENT
N
LEGEND - LEGENDE
3N Norite
Norite
IGA Granite breccia
Brèche granitique
M6 Granite gneiss
Gneiss granitique
Stopes - 300 level
Chantiers - niveau 300
Swamp
Marécage
Major ore zones
Zones minéralisées principales
Test hole
Sondage
0 100 200
feet - pieds

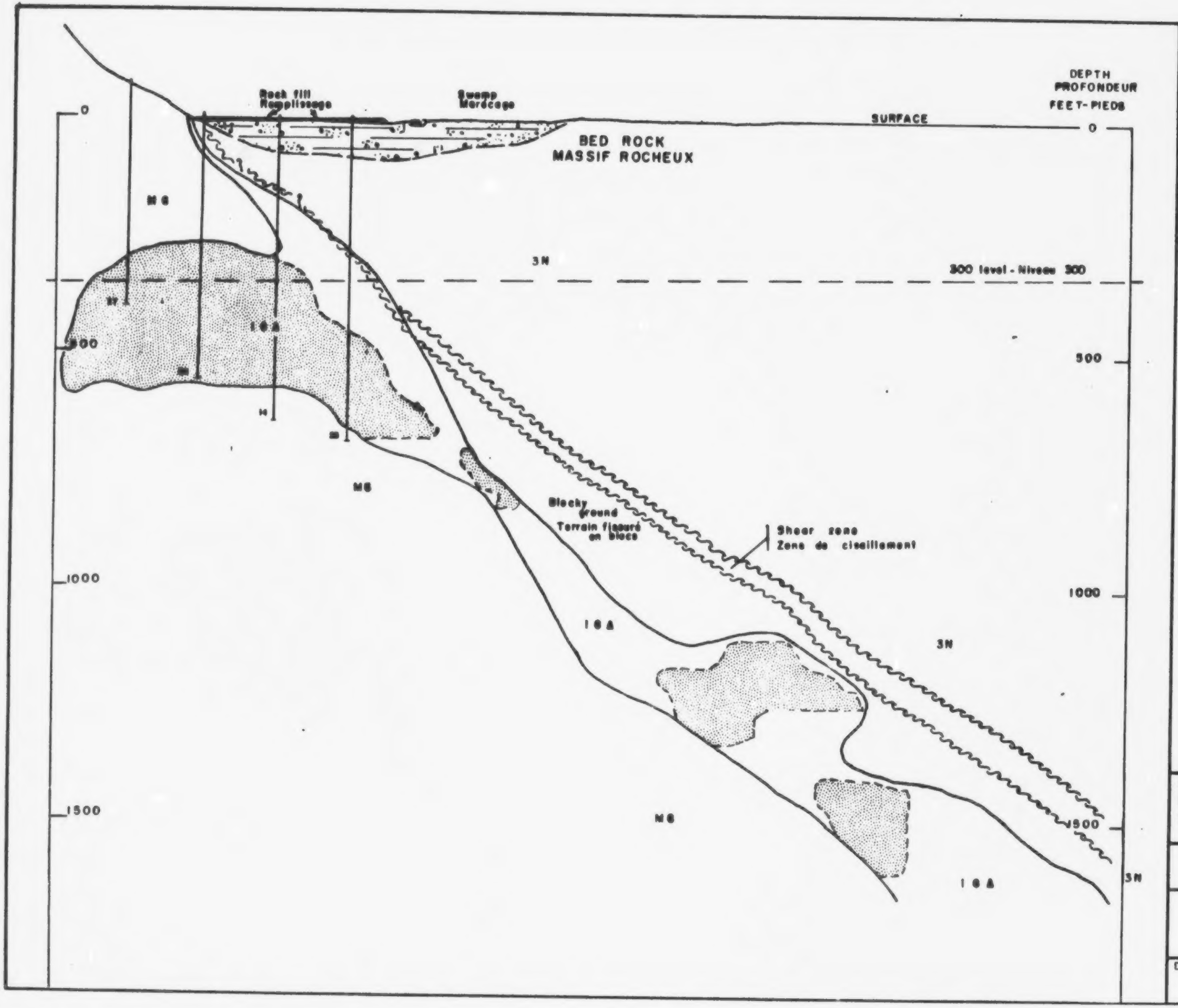
ROCHE
associés ltée
Groupe conseil

2535 boul Laurier
Sainte-Foy Québec
G1V 4M1 Canada
(418) [illegible]
Télex [illegible] 051 31593

MINE # 9 MINE

SURFACE PLAN
PLAN DE SURFACE

Date	Figure
06/85	9.2


DEPTH
PROFONDEUR
FEET-PIEDS
0
500
1000
1500
0
500
1000
1500
Rock fill
Remplissage
Swamp
Marécage
SURFACE
BED ROCK
MASSIF ROCHEUX
MG
3N
300 level - Niveau 300
IGA
MG
Blocky ground
Terrain fissuré en blocs
Shear zone
Zone de cisaillement
IGA
3N
MG
IGA
3N

LEGEND - LEGENDE

▨ Major ore zones
Zones minéralisées principales

MG Granite gneiss
Gneiss granitique

IG ▲ Granite breccia
Brèche granitique

3N Norite
Norite

〰 Hanging wall shear
Faille de toit (Faille supérieure)

0 100 200
FEET-PIEDS

SECTION A-A'
COUPE

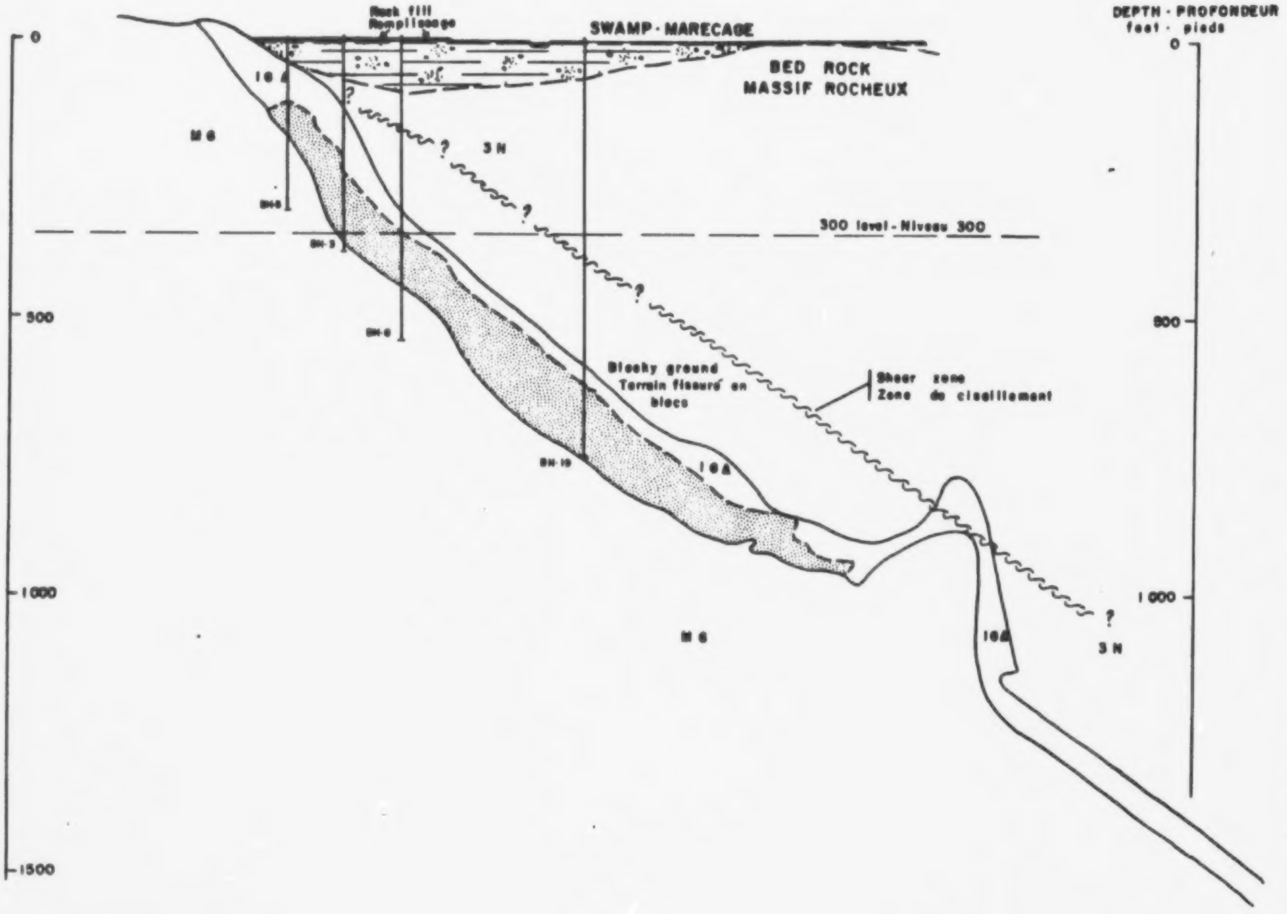
ROCHE
associés ltée
Groupe conseil

2535, boul Laurier
Sainte-Foy, Québec
G1V 4M3 Canada
(418) [illegible]
Télex [illegible]

MINE # 9 MINE

GEOLOGICAL SECTION
COUPE GEOLOGIQUE

Date 07/85
Figure 9.3


DEPTH - PROFONDEUR
feet - pieds
0
500
1000
1500
Rock fill
Remplissage
SWAMP - MARECAGE
BED ROCK
MASSIF ROCHEUX
16 A
M 6
3 N
BH-8
BH-3
BH-6
BH-10
300 level - Niveau 300
Blocky ground
Terrain fissuré en blocs
Shear zone
Zone de cisaillement
?
16 A
M 6
3 N

LEGEND - LEGENDE

▨	Major ore zones Zones minéralisées principales
M 6	Granite gneiss Gneiss granitique
16 A	Granite breccia Brèche granitique
3 N	Norite Norite
〰	Hanging wall shear Faille de toit (faille supérieure)

0 100 200
feet - pieds

SECTION
COUPE B-B'

ROCHE

MINE # 9 MINE

GEOLOGICAL SECTION
COUPE GEOLOGIQUE

Date	Figure
07/85	9.4

. Characteristics of the Deposit

The property is composed of four (4) distinct ore zones. We will concentrate, however, on the principal zone which reaches the surface and contains the surface pillars. The ore appears in the form of massive sulfides inside granite breccia and in the form of veins in the rocks of the footwall.

According to the comments made by mine personnel, the metallic deposit has its origin in the intrusion (through the breccia) of acid rocks rich in nickel and copper.

Near the surface, as shown in figures 9.2, 9.3 and 9.4, the western part of the mine differs considerably from the eastern part. On that side, the ore zone forms a pocket of about 700 ft x 450 ft (210 x 135 m), plan view, by 300 ft (90 m) in height, before plunging at 40°S. The western part, on the other hand, maintains 50 to 100 ft (15 to 30 m) along its entire length and plunges likewise at 40-45°S. The two zones join at level 3 and continue to about 3 600 ft (1 097 m) below the surface.

The property has been in production since 1913 and current tonnage is 4 000 t/day.

9.2 MINE ENVIRONMENT

The principal deposit dips below a marshy region composed of 45 to 70 ft (13.5 to 21 m) of varied overburden. The principal installations are all located in the footwall of the deposit at more than 500 ft (150 m) from the mining zones, an area where the rock is competent.

Even though the upper stopes have been worked for more than 50 years, NO SIGNS OF SUBSIDENCE are noticeable at the surface. The tailings pound formerly used by the Company is located about 1 mi (1.6 km) from the deposit; presently all the ore extracted from the property is processed elsewhere.

Close to the upper stopes of the mine there is thus no material likely to be affected by, or to have an influence on, the design of the surface pillars. The only noteworthy point is the presence of a marsh fed by a natural stream.

9.3 OVERBURDEN

In 1956, a preliminary study was conducted to determine the possibility of dewatering the marsh. Five (5) drill holes of 10 in Ø (25 cm) were drilled as far as the rock interface and samples taken along the stratigraphic column. Unfortunately, we have no data on the soils encountered except for a visual description of the material.

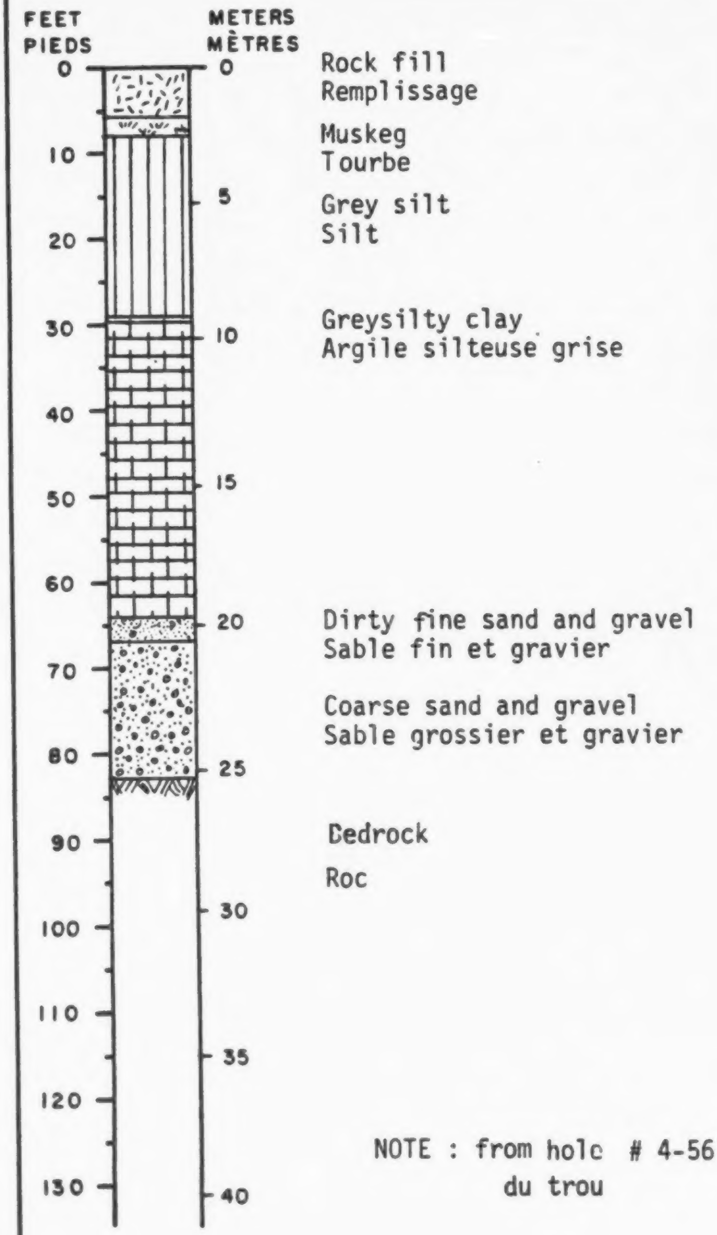
In addition to these five holes, diamond drilling during the exploitation campaigns allow an approximate determination of the rock profile as seen in cross-sections 9.3 and 9.4. According to mine authorities, most of the overburden is composed of hard impermeable clay over sand and gravel.

This was probably the only study done on the overburden in this sector of the property. Finally, it should be mentioned that the use of a few feet of rill allowed the Company to build storage areas or parking lots above the marshland; these additionnal materials have only slightly altered the original conditions and their importance is minimal.

. Stratigraphy and Characteristics

Figure 9.5 shows a sketch of the stratigraphic column above the principal deposit. It should be mentioned that the mine is located on the edge of a valley the bottom of which is covered by glacial deposits. The stratigraphic sequence is typical with the presence of

SOIL STRATIGRAPHY
STRATIGRAPHIE DU SOL


FEET
PIEDS
METERS
MÈTRES
0
10
20
30
40
50
60
70
80
90
100
110
120
130
0
5
10
15
20
25
30
35
40
Rock fill
Remplissage
Muskeg
Tourbe
Grey silt
Silt
Greysilty clay
Argile silteuse grise
Dirty fine sand and gravel
Sable fin et gravier
Coarse sand and gravel
Sable grossier et gravier
Bedrock
Roc

NOTE : from hole # 4-56
du trou

ROCHE associés ltée Groupe-conseil 2535, boul Laurier, Sainte-Foy, Québec G1V 4M3 Canada (418) 871 9800 Télex QBC 051 31593	MINE # 9 MINE	Date 07/85	Figure 9.5

sand/gravel/clay at the rock contact point with a layer of clay/silty clay followed by silt/sand and muskeg at the surface.

However, the sand/gravel layer was not found in all five (5) drill holes. Apparently only the two holes closest to the middle of the swamp (bottom of the basin) came across this formation. These holes are shown on the surface plane and are numbered 4 and 5.

There is a possibility that these soils erode depending on the size of the cut through the rock section. However, it must be noted that this possibility is highly improbable. The resistance of hard clay is an important factor in the stability of these soils.

The upper stopes have been worked and filled for more than 20 years and the marshland has remained unchanged since the beginning.

9.4 ROCK MASS

. Nature of the Rock

Aside from the identification of the principal formation, as already outlined in the section on geology, no other data on the nature of the rock was available.

. Structural geology

Although no data was available at the mine, some publications on the region mention that the strike of the foliation is NE-SW dipping at an angle of about 45°S which corresponds to the strike of the mine's longitudinal axis and to its average slope.

. Characteristics

No factual data was available on the site, though it was said that the norite making up the hanging wall is relatively competent. Several writers define the characteristics of the norite as follows:

Density : 3.0
Compressive strength : 27.5×10^3 psi (190 MPa)
Poisson's ratio : 0.17 - 0.20
Young's modulus : $7.0 - 9.0 \times 10^6$ psi
(48 - 62 GPa)

The footwall, given its granitization, is also competent. The stability of the openings is thus directly related to the zone of granite breccia and to the zone affected by the fault, both located in the hanging wall of the deposit.

9.5 HYDROGEOLOGICAL CONDITIONS

. Overburden

The geotechnical tests already described in the preceding section made it possible to conduct pumping trials. These tests lead to the conclusion that the sand and gravel layer located at the rock interface carries away the water, which seems to be trapped by the clay and the silts that are only very slightly permeable. The study concludes that it is possible to pump out this gravelled area as it would seem, from initial analysis, that the capacity of this "reservoir" is relataively small as is its intake. The water table was lowered from 5 to 60 ft (1.5 to 18 m) in one of the drill holes by a twelve (12) hour pump test, pumping at a rate of 183 (I) GPM (14 L/s). The piezometric level returned slowly, rising from 19.5 ft to 6.7 ft (6 to 2 m) under the surface in thirty one (31) hours. This explains the conclusions expressed above.

Naturally, the total amount of water instantly available is considerable if the overburden is left as is. However, under normal operating conditions the mine has no serious water problem in the underground stopes. As the water table is situated above a layer of impermeable clay and silt, there is very little surface water infiltration.

. Rock Mass

The rock mass has not been analysed for permeability. The norite, forming the bulk of the bottom of the marshland is almost unfractured so water infiltration in the mine is minimal. In all 280 (I) GPM (21 L/s) are pumped from the stopes including water produced by the hydraulic fill. The relative percentages of these two sources of water are, however, not known.

The operators indicated that no special measures have been taken to drain the marshland nor control water infiltration in the rock. They use a standard pumping system with ditches and a sedimentation basin.

9.6 MINING OPERATIONS

. Mining methods

Since 1930, mining methods have been used in the following percentages:

Shrinkage stoping (beginning of the operation)	0%
Undermine and fill	25%
Cut-and-fill	13%
VRM (in working the pillars)	62%

The upper levels of the mine, immediately beneath the surface pillar were worked by the shrinkage stoping method, filled either with bulk rock or with natural sand and gravel. The stopes were 1 000 ft (30 m) long on the average and were separated by 40 ft (12 m) transverse pillars. The average depth in the western portion of the deposit was 70 ft (21 m) though the eastern sector in general indicates much more massive geometry. The sublevels were established at a height of 120 ft (36 m).

. Operating Conditions

Overall, mining was carried out from the top of the deposit towards the bottom. Inside the stopes, except where undermining techniques were used, the deposit was worked from bottom to top. The methods used resulted in 71 to 72% ore recuperation. Eventually, the operators hope to mine the pillars thus attaining 95% recuperation.

9.7 SUPPORT AND REINFORCEMENT METHODS

. Primary Support

In the upper and western portions of the mine, along the longitudinal axis of the deposit, rib pillars, 40 ft (12 m) wide, were left for primary support. In the eastern sector, pillars were more irregularly spaced as shown in Figure 9.2. It would seem that the stopes in this sector were left open for several years before being filled which would indicate that the pillars were adequate since they alone supported the weight of the hanging wall and held up to horizontal tectonic stress, as far as the sill pillar located about 620 ft (186 m) below the surface. Almost all the original deep pillars have been mined to date.

. Filling and Reinforcement

Again excluding the upper part of the mine, from the surface to 620 ft (186 m), all stopes were hydraulically filled with cemented sand in a ratio of 1:25. The filling rate is about 500 t per day.

Locally, wall and crown support is assured at 82% by conventional bolts of 5 ft (1.5 m) and 8 ft (2.4 m), at 10% by resin anchored steel rebars, at 4% by 6 ft (1.8 m) split sets and at 4% with swellex stabilizers. The last three categories are used for particular jobs such as retaining webbing against hydraulic fill (in the case of recuperation of the pillars) and to maintain the permanence of access drifts or drawing points.

About 10% of the bolts are checked with a dynamometric key by a qualified person to insure a tightness of at least 125 lbs. ft (169 N.m).

9.8 MONITORING PROGRAM

. Stress Measurement

Not applicable in this case.

. Displacement Measurments

Not applicable in this case.

. Other programs

This operation has had few problems in the surface pillar zone. For this reason, they have no monitoring program on the surface pillars.

On the other hand the most important feature of the operation is the progressive cave-in of the roof of a stope at level 11. This type of cave-in is called a piping effect. It consists of progressive crumbling of the solid rock which then falls into the underlying stope. The mechanisms involved are still difficult to explain today. This has not affected the surface pillar zone, but it is worth noting that the crown of this stope has caved-in at a height of more than 600 ft (180 m) from the surface. The Company has used fill, introduced through two (2) surface holes to successfully check the progressive cave-in of the stope. Later, three survey drillings confirmed that the phenomenon had ceased.

9.9 SURFACE PILLAR DESIGN

. Personnel Involved

At this property, the personnel is concentrating its efforts on the mining of the rib pillars throughout the mine. Little attention is given, as has been pointed out, to old stopes worked in the 1930-40's. However, the Company recently undertook the necessary preparations for the extraction of pillars 2, 4 and 6 of the upper part of the eastern zone of the main deposit. The Mine Engineering Department is responsable for this work. It is helped in this task by the Company's Rock Mechanics Department which oversees several properties. They tell us that the evaluation of the effects of the extraction from these pillars will be studied on the short term. At the time of our visit, no data was available.

. Chronology

The Company did not have to "design", as such, the surface pillars. The deposit was worked to the upper economical limit located between 50 and 200 ft (15 and 60 m) from the rock/soil interface. Also, the design of the dimensions and the number of rib pillars was determined according to general standards. The dimensions of the surface pillars have been established since the mining of the upper stopes and will not vary in the future.

. Design Factors

Because of the dip deposit, the crown is mainly formed by the hanging wall as shown in figures 9.2 and 9.3. For this reason, about 40/140 (29%) of the ore zone was left as rib pillars.

. Pillar Dimensions

Longitudinal section 9.6 illustrates the layout of the stopes. It clearly shows the difficulty of identifying a single, monolithic surface pillar for this type of deposit. Thus we have indicated the approximate position of the rock above each of the stopes, giving the minimal thickness of the surface pillars. The nine (9) pillars correspond to crowns in the upper stopes of the mine. Surface pillar # 8 is singular because of its dimensions and because of the presence of a longitudinal pillar as shown in Figure 9.2.

Table 9.1 summarizes the dimensions of all surface pillars on this property.

As already indicated, this Company operates several mines with a centralized rock mechanics service.

We have thereby discussed the case of a second operation in which an old surface pillar will very likely be partially mined. The Company's approach is as follow:

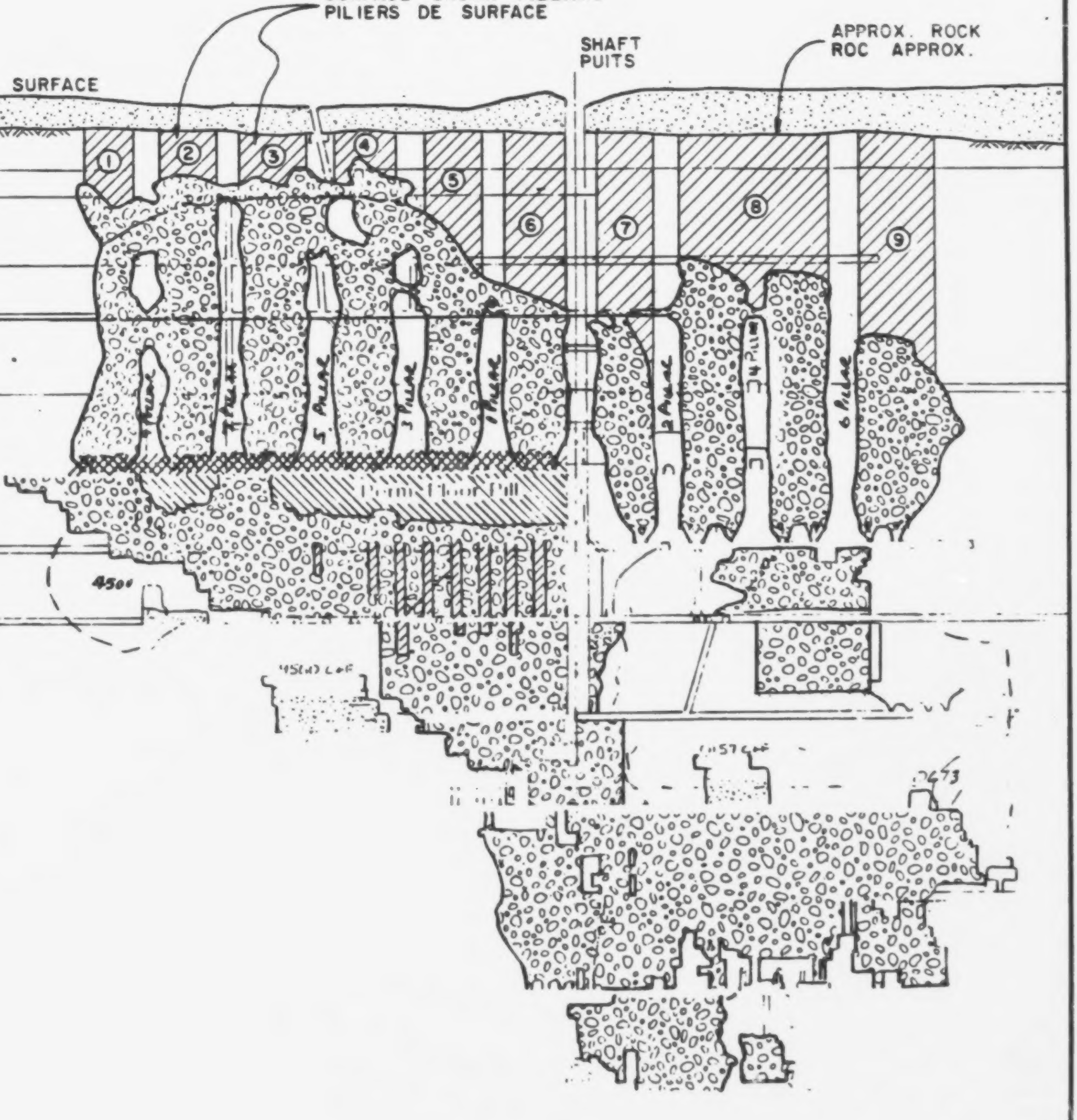

SURFACE CROWN PILLARS
PILIERS DE SURFACE
SHAFT
PUITS
APPROX. ROCK
ROC APPROX.
SURFACE
①
②
③
④
⑤
⑥
⑦
⑧
⑨
9 Pillar
7 Pillar
5 Pillar
3 Pillar
1 Pillar
2 Pillar
4 Pillar
6 Pillar
Perm Floor Pill
4500

Fig. 9.6 Main orebody - longitudinal section
Gisement principal - coupe longitudinale

DIMENSIONS OF SURFACE CROWN PILLARS

DIMENSIONS DES PILIERS DE SURFACE

TABLE 9.1
TABLEAU 9.1

DIMENSIONS		PILLARS - PILIERS							
		#1	#2	#3	#4	#5	#6	#7	#8
. THICKNESS: EPAISSEUR:									
- WATER BODY PLANS D'EAU	feet-pi. (m)	-	-	-	-	-	-	-	-
- OVERBURDEN MORTS-TERRAINS	feet-pi. (m)	45 (13.7)	45 (13.7)	45 (13.7	45 (13.7)	45 (13.7)	60 (18.3)	65 19.8)	75 (22.9)
. SURFACE CROWN PILLAR: PILIER DE SURFACE:									
- THICKNESS EPAISSEUR	feet-pi. (m)	110 (33.5)	70 (21.3)	65 (19.8)	55 (16.8)	175 (53.4)	270 (82.3)	285 (86.9)	220 (67.0)
- WIDTH LARGEUR	feet-pi. (m)	35 (10.7)	35 (10.7)	45 (13.7)	45 (13.7)	60 (18.3)	60 (18.3)	60 (18.3)	240 (73.2)
- LENGTH LONGUEUR	feet-pi. (m)	50 (15.2)	100 (30.5)	140 (42.7)	80 (24.4)	60 (18.3)	95 (29.0)	80 (24.4)	520 (158.5)
- THICKNESS/WIDTH RATIO RAPPORT EPAISSEUR/LARGEUR		(3.1)	2.0	1.4	1.2	2.9	4.5	4.8	0.9
. STOPE HEIGHT HAUTEUR DU CHANTIER	feet-pi. (m)	420 (128.1)	450 (137.2)	440 (134.1)	460 (140.2)	360 (109.8)	250 (76.2)	340 (103.7)	430 (131.1)
. FILL HEIGHT HAUTEUR DU REMBLAI	feet-pi. (m)	420 (128.1)	450 (137.2)	440 (134.1)	460 (140.2)	360 (109.8)	250 (76.2)	340 (103.7)	430 (131.1)

DIMENSIONS OF SURFACE CROWN PILLARS

DIMENSIONS DES PILIERS DE SURFACE

TABLE 9.1
TABLEAU 9.1

DIMENSIONS		PILLARS - PILIERS							
		#9							
. THICKNESS: EPAISSEUR:									
- WATER BODY PLANS D'EAU	feet-pi. (m)	-							
- OVERBURDEN MORTS-TERRAINS	feet-pi. (m)	70 (21.3)							
. SURFACE CROWN PILLAR: PILIER DE SURFACE:									
- THICKNESS EPAISSEUR	feet-pi. (m)	335 (102.1)							
- WIDTH LARGEUR	feet-pi. (m)	100 (30.5)							
- LENGTH LONGUEUR	feet-pi. (m)	150 (45.7)							
- THICKNESS/WIDTH RATIO RAPPORT EPAISSEUR/LARGEUR		3.4							
. STOPE HEIGHT HAUTEUR DU CHANTIER	feet-pi. (m)	310 (94.5)							
. FILL HEIGHT HAUTEUR DU REMBLAI	feet-pi. (m)								

1. Evaluation of the state of the existing stopes left without fill for several years and then partially filled.

2. Seismic reading taken above the future zone of exploitation in order to confirm the depth of the overburden. A degree of precision of ± 4 ft (1.2 m) is required. The company wants to confirm the values obtained from 2 or 3 diamond drillings.

3. During the preparation of the future zone of exploitation, drilling will be carried forward, upward and sideways from the access forward, drift in order to delect the presence of aquifers.

4. Drilling from the mining drift in the new surface pillar area in the least three (3) places along the width (approximately) 550 ft: 168 m of the intended stope.

5. Determination of the operating conditions and required support.

6. Determination of the ultimate thickness of the surface pillar and the calculation of a security factor.

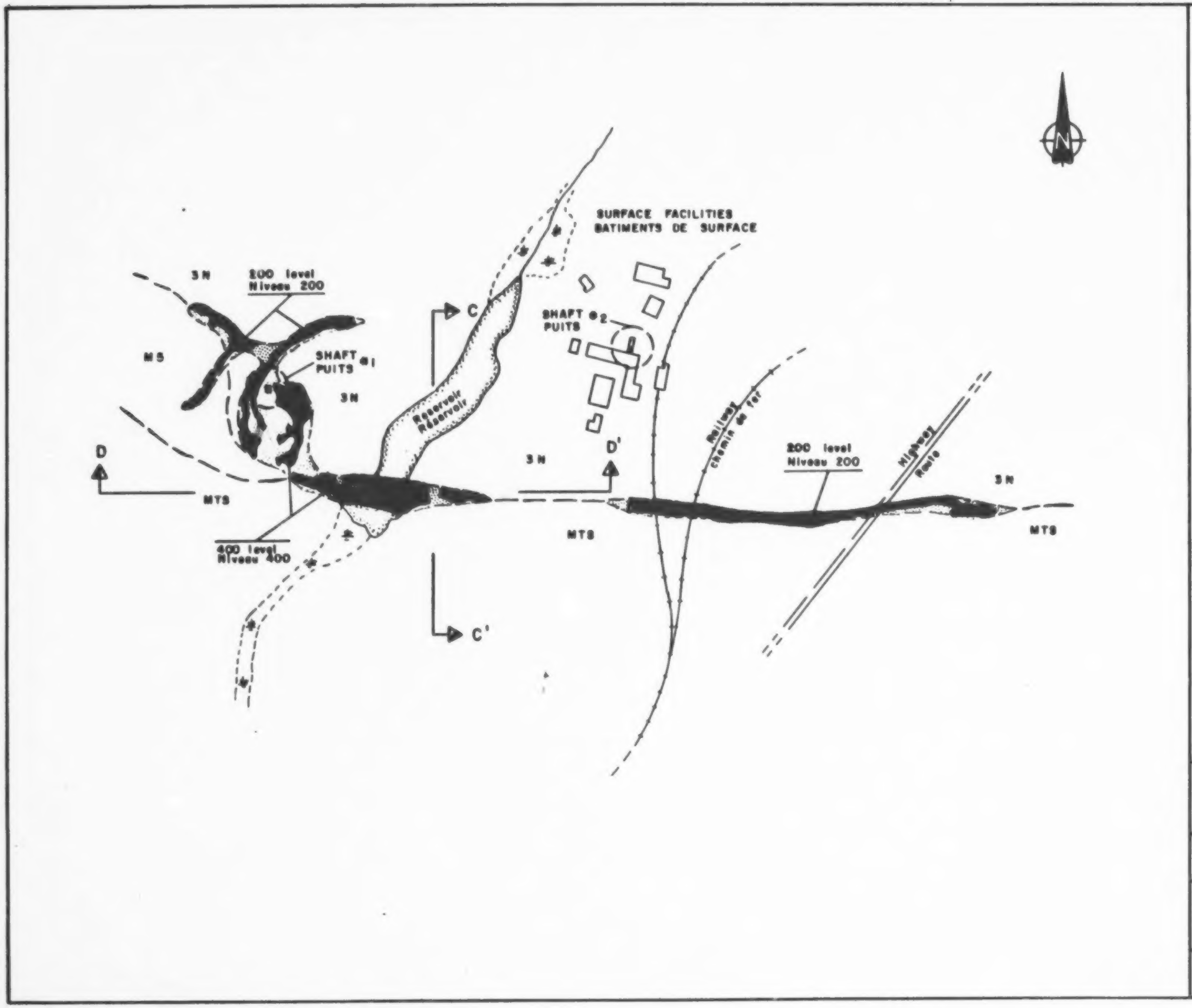
As is evident, the Company's approach is based on a qualitative evaluation of the rock mass and on a mathematical model.

Figures 9.7, 9.8 and 9.9 represent this case in point. The present pillar is approximately 400 ft (122 m) in length. Management plans to use the "VRM" method taking slices of a maximal length of 30 ft (9.1 m); the width of the eventual stope should not exceed 50 ft (15 m).

It was proposed that a residual surface pillar with a thickness of 50 ft (15 M) be left. The entire underside of the surface pillar will be exposed by a full width section; from this surface longholes will be drilled downwards. It is therefore expected that grouted cables 25 ft (7.6 m) long will be used in a 7 x 7 ft pattern (2.1 x 2.1 m) in order to support the topsill. In addition, cemented hydraulic fill will be used. Finally, it is noteworthy that slices will be extracted sequentially; i.e (1) every second (30 ft) stope will be mined (2) these will then be filled before the secondary stopes are mined. In this way, the maximum unsupported gap left open at any one time will measure 30 ft (9.1 m) in length and 50 ft (15 m) in width.

The planning for the partial extraction of this pillar has been completed, or perhaps more accurately, the calculation of the security factor has been made. It is of interest to review the calculation procedure and the hypotheses used to obtain the result.

Firstly, the members of the Rock Mechanics Department determined that the rock mass in very competent; based on mining experience on this property, the RQD value is of 60 to 70%, the measure of the compressive strength of the intact rock sets at approximately 20 000 psi (138 MPa).


N
3 N
200 level
Niveau 200
M 5
SHAFT #1
PUITS
3 N
D
MTS
400 level
Niveau 400
C
Reservoir
Réservoir
C'
SURFACE FACILITIES
BATIMENTS DE SURFACE
SHAFT #2
PUITS
3 N
D'
MTS
Railway
chemin de fer
200 level
Niveau 200
Highway
Route
3 N
MTS

LEGEND - LEGENDE

3 N	Norite Norite
M 5	Gneiss Gneiss
MTS	Metasediment Metasediment
▨	Ore zone Zone minéralisée
■	Stope Chantier
~	Geological contact Contact géologique

0 200 400
feet - pieds

ROCHE
associés ltée
Groupe conseil

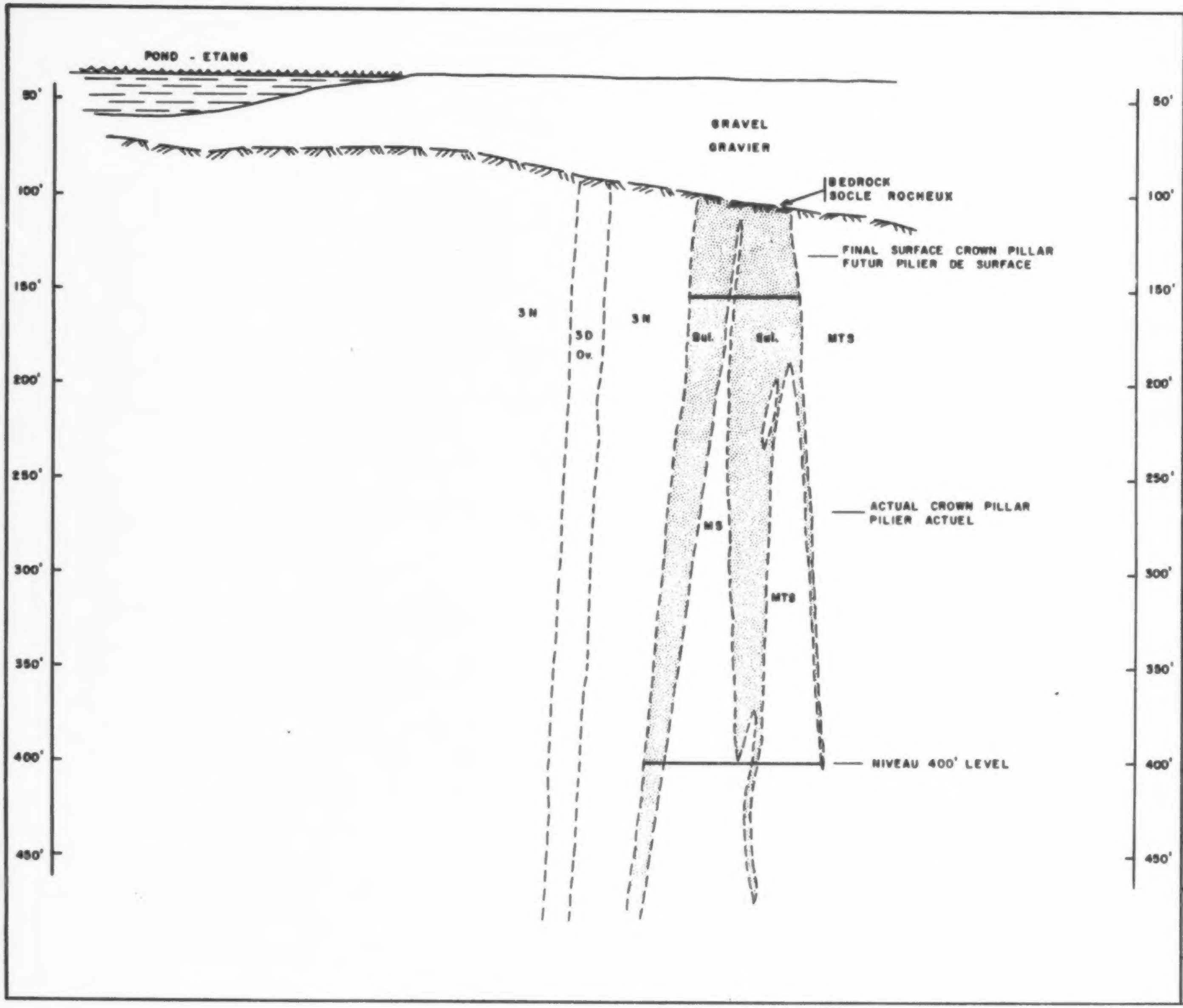
2535 boul. Laurier
Sainte-Foy, Québec
G1V [illegible] Canada
(418) 871 [illegible]
Télex [illegible]

MINE #9 MINE

SURFACE PLAN
PLAN DE SURFACE

Date 07 / 85

Figure 9.7


POND - ETANG
GRAVEL
GRAVIER
BEDROCK
SOCLE ROCHEUX
FINAL SURFACE CROWN PILLAR
FUTUR PILIER DE SURFACE
ACTUAL CROWN PILLAR
PILIER ACTUEL
NIVEAU 400' LEVEL
3 N
3 D
Ov.
3 N
Sul.
Sul.
MTS
MS
MTS
50'
100'
150'
200'
250'
300'
350'
400'
450'

LEGEND-LEGENDE

3 D	Diabase Diabase
3 N	Norite Norite
M S	Gneiss Gneiss
Sul.	Sulfides Sulfures
Ov.	Olivine Olivine
MTS	Metasediment Métasédiments
▨	Ore zone Zone minéralisée

SECTION
COUPE C-C'

0 25 50
feet-pieds

ROCHE
associés ltée
Groupe conseil

2535 boul Laurier
Sainte-Foy Québec
G1V 4M3 Canada
(418) 871 [illegible]
Télex [illegible]

MINE # 9 MINE

GEOLOGICAL SECTION
COUPE GEOLOGIQUE

Date
07 - 1985

Figure
9.8

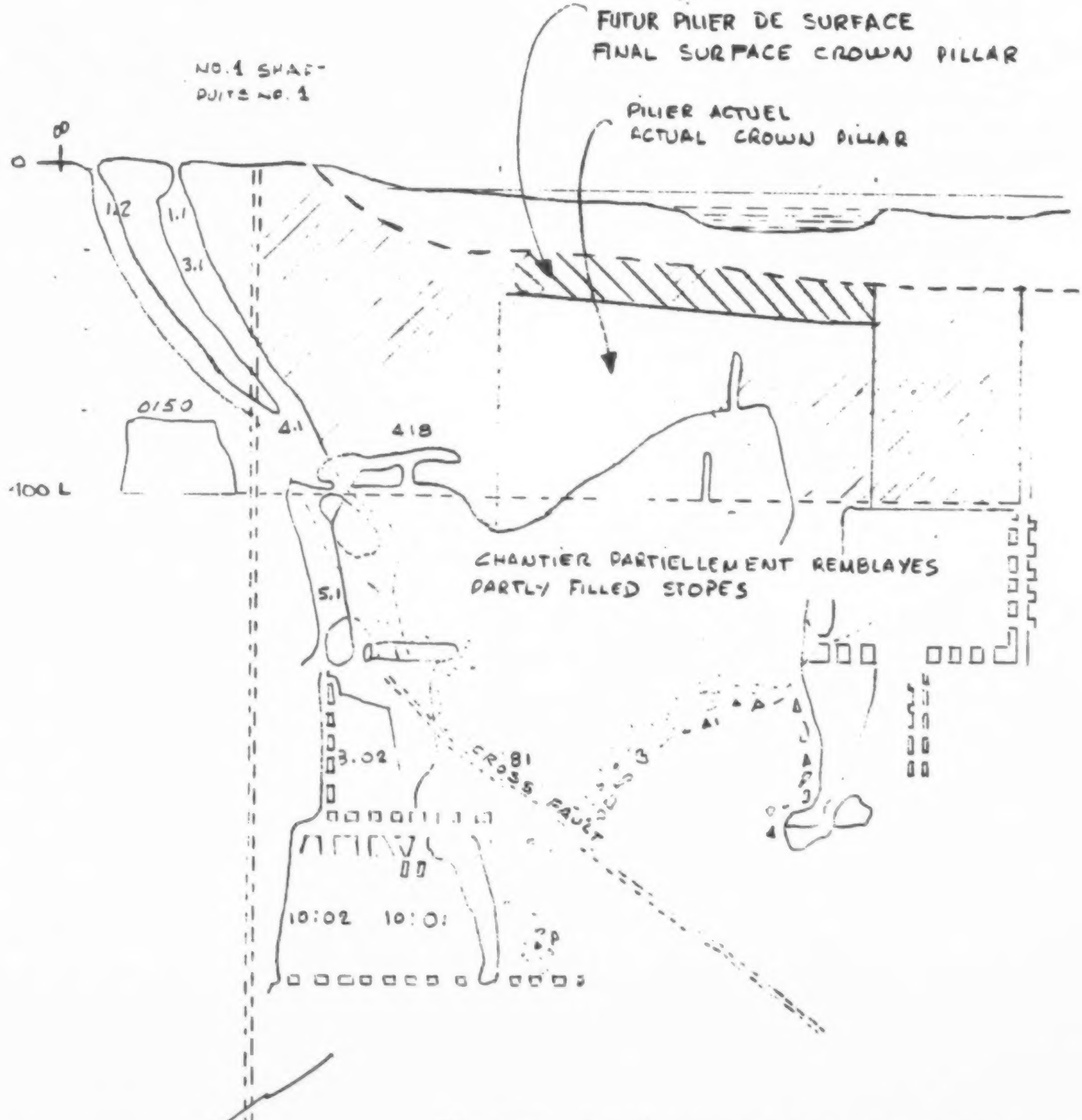

FUTUR PILIER DE SURFACE
FINAL SURFACE CROWN PILLAR
NO.1 SHAFT
PUITS NO. 1
PILIER ACTUEL
ACTUAL CROWN PILLAR
0
00
1.2
1.1
3.1
0150
4.1
418
-100 L
CHANTIER PARTIELLEMENT REMBLAYES
PARTLY FILLED STOPES
5.1
3.02
81
CROSS FAULT
3
10:02
10:01

Fig. 9.9. D-D' LONGITUDINAL SECTION
COUPE LONGITUDINALE D-D'

Scale - Echelle
1"= 200'

It is therefore reasonable to use the general equations for calculating the stresses and the strength on the rock mass. Since the Company had already determined the state of natural stresses in this region, there was much basic data readily available.

The hypotheses put forward were as follows:

(1) Since the strike of the mining will be E-W, the stress that is mot likely to affect the residual surface pillar is the N-S stress.

(2) The mining of part of the existing surface pillar will transfer approximately 2/3 of the stress onto the residual pillar - since the underlying stopes will have already been mined.

(3) The compressive strength of one (1) ft' of rock is estimated at 14 000 psi (96.5 MPa). This leaves an adequate safety margin since the value normally used elsewhere in the mine is 16 000 psi (110.3 MPa).

Based on these hypotheses, the calculation procedure is as follows:

(1) Evaluation of the residual surface pillars, before the mining of the stopes, using the relationship between horizontal and vertical stress.

$$\sigma_h = 1\ 180 \text{ psi} + 1.842\ H$$

where H= the depth in ft of a point in the rock mass.

Presently, the σ_h half way up the future 50 ft surface pillar will be:

$$\sigma_h = \left[1180 + 1.842\ (25)\right] \times 1.6/1.8$$

where the ratio of the horizontal stresses in the NS strike is 1.6/1.8. For the EW strike, the net horizontal stress becomes:

$$\sigma_h = 1090 \text{ psi } (7.5 \text{ MPa})$$

in the same manner, since the present pillar is 300 ft (91 cm) thick, halfway up, we will have:

$$\begin{aligned}\sigma_h \text{ (future stope) } &= \left[1180 + 1.842\ (150)\right] \times 1.6/1.8 \\ &= 1295 \text{ psi } (8.9 \text{ MPa})\end{aligned}$$

While mining part of the existing surface pillar, 2/3 of the stresses will be redistributed over the 50 ft (15 m) thick residual pillar. The stresses acting on the latter will be expressed by the following equation:

1. σ_h (stress in the future surface pillar)= the present stress + the extra burden imposed by the mining of the existing surface pillar (2/3 of the calculated stresses).

$$\begin{aligned}\sigma_h \text{ (stress in the future surface pillar) } &= \left[1090 + (1295 \times 180/50)\right] \times 2/3 \\ &= 4215 \text{ psi } (29 \text{ MPa})\end{aligned}$$

2. Moreover, the strength of the residual surface pillar is evaluated by a formula adapted to underground pillars in this mining sector where:

   σ_h (residual pillar strength)=

   $1.4 \times 14\,000 \times 50^{0.46} / 50^{0.66}$

   This equation takes into account the strength of a one cubic ft block of rock from the center and in the form of the pillar itself.

   σ (residual pillar strength)= 8965 psi (62MPa)

3. The security factor is obtained by comparing the stregth of the residual surface pillar to the stress acting on it.

   F.S. = 8965/4215 = 2.1

   The calculation method based on the verified hypothesis that the area is relatively homogeneous, permits an overview of the phenomena acting on the rock mass. These results will be verified once the Company decides to mine the future stope.

9.10 VISUAL EVALUATION OF THE SURFACE PILLAR(S)

It was not possible to see these pillars as all primary stopes have been filled.

9.11 MANAGEMENT'S COMMENTS

The comments gathered at this Company come from a member of the Rock Mechanics Department. This person is of the opinion that the surface pillars must be treated like regular pillars (horizontal). The calculation example provided in the previous section demonstrates this clearly.

Moreover, the Company seem to be interested in the measurement of the natural stress field. In fact, the equations governing the relationship between the vertical and horizontal stress come from practical readings taken at depths of 300 ft or more. It would therefore be interesting to verify if the extrapolation of the curves is precise.

MINE #10

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10.0 SUMMARY OF THE VISIT

The deposit consists of a band of massive siderite striking in an east-west direction and dipping at 60-80° towards the south. The surface pillar has been worked almost entirely and only three places remain where the pillar has not been touched.

First place:

Beneath a lake (dewatered by the Company) where an oxidation zone runs as far as 150 ft (45 m) below the overburden-rock interface. The area requires protection.

Second place:

Part of the rock mass where two dykes made of diabase cut across the deposit at 70°. These dykes divide the deposit into two zones (east and west). This part of the rock mass is considered as waste.

Third place:

Part of the band of siderite is less than 25 ft (7.5 m) wide, in the eastern zone. Because of the slight width and variable dilution, this part of the deposit is not economically viable.

Two open pit mines, non-operational since 1950, were used for partial mining of the surface pillar. Three times between 1969 and 1970, slides from the rock walls partly filled one of these open pits and plugged the upper underground stopes.

In the extreme eastern part of the deposit, a chimney has developed from the 300 ft (90 m) level rising to the surface. This chimney gradually increased in size over a six month period and caused a caved-in area at the surface, 500 ft (150 m) by 600 ft (180 m) where the subsidence reaches 100 ft (30 m) in some places. The phenomenon seems to be due to the high degree of fracturing of the rock in this part of the deposit.

10.1 GENERAL INFORMATION

. Regional Geology

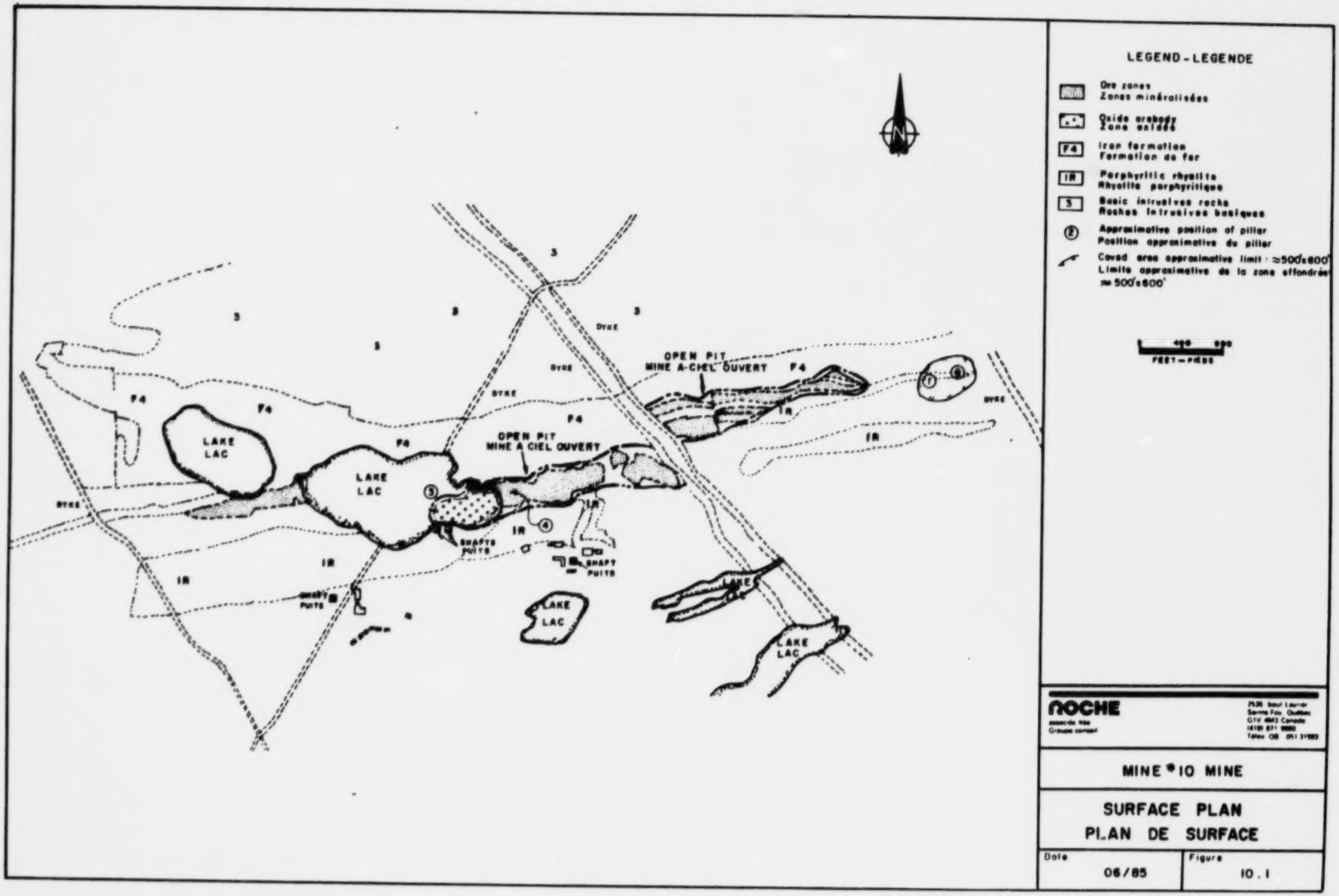
Regional geology consists of a complicated assemblage of metavolcanic and metasedimentary rock situated in the Superior Province. The rocks are Precambrian and are characterized by folds running on an east-west axis and generally dipping 60° to the east. A series of transversal faults covers the region following a north-west direction. The mining property is located in the southern part of an inverted syncline running north. The syncline dips to the east at 40-60° in the vicinity of the mine. A metamorphic green schist facies is typical of the region.

. Local Geology

Local geology may be described as a series of volcanic rocks composed of acid to basic tuff, a massive band of siderite, a massive band of siderite-pyrite, a formation of ferrous chert and siderite and a band of pillow lava (see figures 10.1 and 10.2). Under the effects of the different phases of the folding process, the geological footwall became the hanging wall from a mining stand-point.

. Characteristics of the Deposit

The deposit is made up of a massive band of siderite as part of a series of volcanic rocks.



LAKE LAC
LAKE LAC
LAKE LAC
LAKE LAC
LAKE
OPEN PIT MINE A-CIEL OUVERT
OPEN PIT MINE A CIEL OUVERT
SHAFTS PUITS
SHAFT PUITS
SHAFT PUITS
DYKE
F4
IR
3
①
③
④
N
LEGEND - LEGENDE
Ore zones
Zones minéralisées
Oxide orebody
Zone oxidée
F4
Iron formation
Formation de fer
IR
Porphyritic rhyolite
Rhyolite porphyritique
3
Basic intrusives rocks
Roches intrusives basiques
②
Approximative position of pillar
Position approximative du pillier
Caved area approximative limit : ≈500'x600'
Limite approximative de la zone effondrée ≈500'x600'
0
400
800
FEET - PIEDS

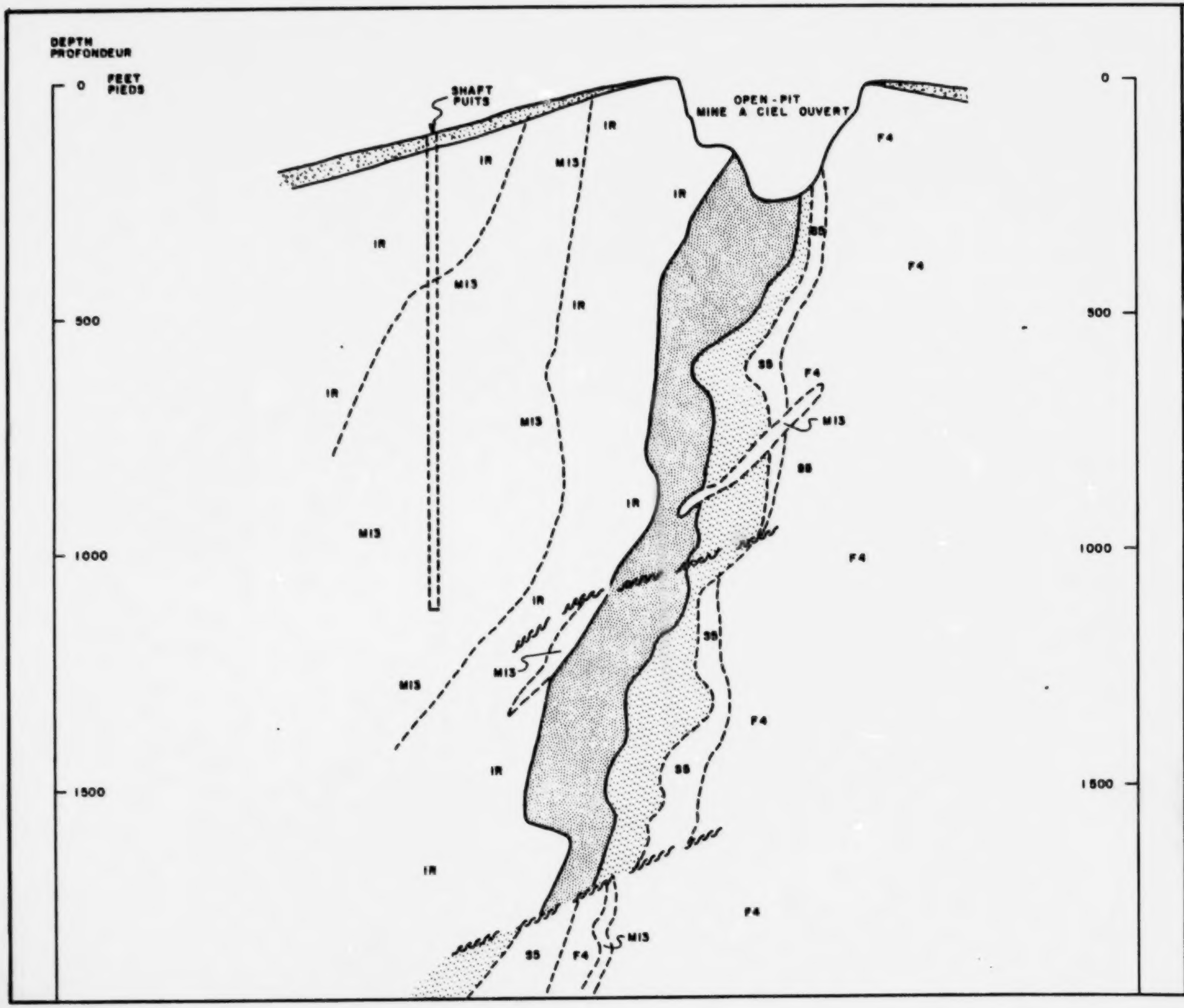
ROCHE
associés ltée
Groupe conseil

2535 boul Laurier
Sainte-Foy, Québec
G1V 4M3 Canada
(418) 871 9880
Télex CB 051 31593

MINE #10 MINE

SURFACE PLAN
PLAN DE SURFACE

Date	Figure
06/85	10.1


DEPTH
PROFONDEUR
FEET
PIEDS
0
500
1000
1500
SHAFT
PUITS
OPEN-PIT
MINE A CIEL OUVERT
IR
M13
F4
SS
IR
M13
IR
M13
IR
IR
M13
M13
IR
M13
IR
IR
F4
F4
SS
F4
M13
SS
SS
F4
SS
SS
F4
M13
SS
F4
0
500
1000
1500

LEGEND-LEGENDE

- ▨ Ore zone : Siderite
  Zone minéralisée : Sidérite
- ░ Siderite - Pyrite
  Sidérite - Pyrite
- F4 Iron formation
  Formation de fer
- M13 Metadiorite
  Métadiorite
- IR Porphyritic rhyolite
  Rhyolite porphyrique
- SS Granular silica
  Quartz granulaire
- Faults
  Failles

0 100 200
FEET - PIEDS

TYPICAL SECTION
COUPE TYPE

ROCHE
associés ltée
Groupe-conseil

2535 boul Laurier
Sainte-Foy, Québec
G1V [illegible] Canada
(418) [illegible]
Télex [illegible]

MINE "10 MINE

GEOLOGICAL SECTION
COUPE GEOLOGIQUE

Date 06/85
Figure 10.2

This layer of iron strikes east-west and has a dip ranging from 60-80° to the south. Dimensions of the deposit are:

Length	Width	Depth
7 000 ft	200 ft	3 000 ft
(2 130 m)	(60 m)	(910 m)

Production of iron ore is continuous at about 7 000 short tons per day. This property represents one of the rare underground iron mines producing siderite of volcanic origin containing about 35% iron.

10.2 MINE ENVIRONMENT

A road and two abandonned buildings are found over the untouched part of the surface pillar and two open pit mines cover about three-quarters of the original surface pillar (see Figure 10.1). These two open pits join the upper stopes. A tailings dump is located in the western open pit mine.

Except for landslides occurring in 1969-1970, no surface settlement has been observed over the principal ore zone. However, at the extreme eastern part of the deposit, part of a surface pillar has gradually caved-in. This is mainly due to the very high degree of fracturing of the hanging wall and of the siderite. The surface involved is estimated at 300 000 ft^2 (27 000 m^2).

No other underground mine is located in the vicinity.

10.3 OVERBURDEN

. Studies

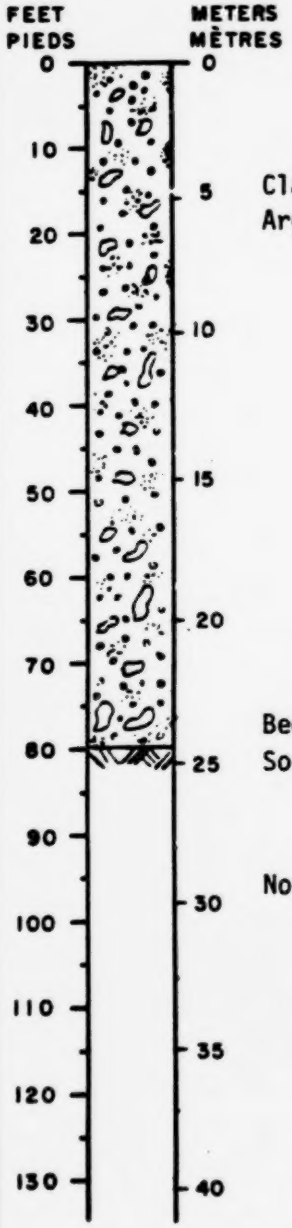
A general profile of the overburden covering the surface pillar could be determined from some drill holes more than 50 years old. The drilling reports were no longer available, but certain plans show the thickness of the loose deposit.

. Stratigraphy and Characteristics

The western portion of the deposit was partially covered by a lake which was later dewatered to permit exploitation. Between the lake bottom and the rock base, there is about 80 ft (24 m) of glacial deposit made up of clay, sand, gravel and boulders (see Figure 10.3). The western part of the mine is covered with deposits of sand, gravel and boulders. The thickness of these deposits varies between 10 and 35 ft (3-11 m).

Most of the overburden above the deposit has been removed with the development of the two open pit mines.

SOIL STRATIGRAPHY
STRATIGRAPHIE DU SOL


FEET
PIEDS
METERS
MÈTRES
0
10
20
30
40
50
60
70
80
90
100
110
120
130
0
5
10
15
20
25
30
35
40

Clay, sand, gravel and boulders
Argile, sable, gravel et blocs

Bedrock
Socle rocheux

Note: - In the west part of the mine, up to 80 feet (24 m) of soil

Dans la partie ouest de la mine, jusqu'à 80 pi (24m) de sol

In the east part of the mine, from 10 to 35 feet (3-11 m) of soil

Dans la partie est de la mine, De 10 à 35 pi (3-11 m) d'épaisseur de sol

ROCHE
associés ltée
Groupe-conseil

2535, boul Laurier,
Sainte-Foy, Québec
G1V 4M3 Canada
(418) 871 9800
Télex: QBC 051 31583

MINE # 10 MINE

Date 07-1985

Figure 10.3

10.4 ROCK MASS

. Nature of the Rock

The rock mass can be described as follows:

Footwall : Alternating chert and siderite
Deposit : Siderite
Hanging wall : Acid to intermediate tuff

In the hanging wall, there is a zone of carbonatization and sericitization extending over 300 feet starting from the deposit. On contact with the dykes that cross the deposit, the siderite was altered and transformed into magnetite.

Porous cavities from a few inches to several hundred feet characterize the footwall and, less often, the band of siderite. These cavities , often flat or elongated, are associated with the presence of metadiorite intrusions. Sometimes, the cavities take a pyramidal shape with the point at the top. In these cavities are found one, or a combination, of the following elements: water, quartz, calcite, pyrite and marcassite.

Below the artificially dewatered lake, an oxidation zone runs as far as 150 ft (45 m) deep into the band of siderite.

In 1963, a sudden eruption of material coming from this zone flooded part of the underlying drifts which had already been abandonned. The material was composed of sand, silica and pyrite saturated with water. Management immediately had barricades installed to prevent further eruptions.

. Structural Geology

Five types of faults and five of major dykes (diabases) characterize the rock mass. No study has been conducted on the joints either at the surface or at the first level. Management did, however, note that joints in the eastern portion of the deposit contained chlorite in some places.

A study effectuated by CANMET indicates that the schistic cleavage strikes ENE-WSW and dips slightly to the NNW or the SSE. Again, according to CANMET, the ratio of horizontal/vertical stress measured at 1 300 ft (396 m) ranges from 1.6 to 2.

. Characteristics

Table 10.1 summarizes the geomechanical properties of the rock mass.

No R.Q.D. value has been computed for this mine. Management does mention, however, that the R.Q.D. of the footwall appears higher than that of the hanging wall. The latter has more faults or fracture planes, generally less than 50 feet long.

The contact point of the ore with the walls is characterized by a band of pyrite-siderite in the footwall

ROCK CHARACTERISTICS

CARACTÉRISTIQUES DE LA ROCHE

TABLE 10.1

TABLEAU 10.1

LOCATION EMPLACEMENT		FOOT WALL ÉPONTE INFÉRIEURE	OREBODY GISEMENT	HANGING WALL ÉPONTE SUPÉRIEURE	
ROCK TYPE TYPE DE ROCHE		CHERT - SIDERITE	SIDERITE	METADIORITE	TUF
DENSITY DENSITÉ		2.93	3.56	2.90	2.88
COMPRESSIVE STRENGTH RÉSISTANCE EN COMPRESSION	psi x 10^3 (MPa)	39.8 (274)	38.5 (265)	21.0 (145)	28.3 (195)
SHEAR STRENGTH RÉSISTANCE AU CISAILLEMENT	psi x 10^3 (MPa)	-	-	-	-
TENSILE STRENGTH RÉSISTANCE EN TENSION	psi x 10^3 (MPa)	-	-	-	-
POINT LOAD STRENGTH INDICE DE DOUBLE POINCONNEMENT	psi x 10^3 (MPa)	-	-	-	-
POISSON'S RATIO RAPPORT DE POISSON		0.22	0.32	0.30	0.26
YOUNG'S MODULUS MODULE DE YOUNG	psi x 10^6 (GPa)	7-14 (48-96)	9-17 (62-117)	5-11 (34-76)	6-10 (41-69)
RQD %		-	-	-	-
GEOMECHANICAL CLASSIFICATION CLASSIFICATION GÉOMÉCANIQUE		-	-	-	-

and by an alteration zone in the hanging wall. A few minor chips, a few inches long are observed in the contact zone.

The average sonic velocity for the whole of the rock mass is 20 350 ft/s (6 203 m/s) for longitudinal waves and 12 040 ft/s (3 670 m/s) for transversal waves.

10.5 HYDROGEOLOGICAL CONDITIONS

. Overburden

The lake which partially covered the western zone of the deposit was dewatered by means of surface pump systems and by a pipeline beginning at an underground level and ending under the lake.

No precise data has been gathered concerning the soils and the piezometric level.

. Rock Mass

Water flow in the rock mass is very limited. Management reports that in certain faults or fracture planes, the water output may reach 1/8 to 1/4 (US)GPM (.008 to 0,016 L/s). For the whole of the underground mine, 500 (US)GPM (32 L/s) is pumped to the surface. This water is pumped from one sump to another by pumping stations situated at three different levels.

During working of the upper stopes, numerous cavities containing water under pressure were encountered. Water pressure in these went as high as 750 psi 5 170 kPa), particularly below the dewatered lake.
Water from the zone under the lake is acidic (pH = 2.5 to 6.5). In one of the stopes under the lake, water intake has reached 100 (US) GPM (6 L/s).

10.6 MINING OPERATIONS

. Mining Methods

The deposit is worked using the open stope and sub-levels method. Wall pillars left during initial stoping were later recuperated.

. Operating Conditions

Stopes are normally 60 feet (18 m) wide and the length varies according to the thickness of the band of siderite. Pillars, 80 feet (24 m) wide, separate the stopes and the levels are 300 feet (91 m) apart.

The extraction percentage in the upper stopes was 100%. Dilution ranges from 0 to 5% in general and comes almost exclusively from the hanging wall.

The production sequence is as follows: mining from top to bottom and retreating to the east and west from the center of the deposit, on several levels simultaneously. The powder factor used in the mining is 0.3 lbs/t (0,13 kg/t) and the drill pattern is as follows:

- Series of drill holes fanned out and oriented on a vertical plane
- Fan spacing: 5 ft (1.5 m)
- Spacing of the drill hole toes: 17 ft (5.1 m) (26 ft : 8 m in the upper part of the mine)
- Hole length: about 70 ft (21 m)
- Diameter: 2 1/8 in (5.5 cm).

The exploited stopes have no major support and no filling has been done. It should be noted that some stopes are more than 80 years old.

Two general mining sequences in the inferior levels of the western part of the deposit were simulated on a computor using a two-dimensional finite element model. The first sequence was similar to that already described and gave a 50% recovery rate. The second sequence, based on the working of one level at a time, resulted in a recovery percentage of 80%.

The basic data used to produce the model were not available. Management adopted the latter sequence four (4) years ago.

10.7 SUPPORT AND REINFORCEMENT METHODS

. Primary Support

The 80 ft (24 m) wide rib pillars are recuperated after the complete working of the primary stopes. In certain lower level stopes, the roof is cut in an arch form for better stress distribution.

. Filling and Reinforcement

As previously mentionned, none of the stopes are filled. Bolting is the principal reinforcement method used in this mine. Conventional bolts and grouted rebars are used in respective proportions of 97% and 2%. Cables are used less than 1% as is steel mesh. Wood is rarely used.

No reinforcement measures have been taken in the upper stopes.

Some traction tests have been done on the bolts and cables installed in the stope roofs; the applied strength ranges from 6 to 10 t for bolts and about 25 t for cables. Spotchecks of the torque are done on about 10% of newly installed bolts. Resin-anchored bolts are pre-tensioned at 150 lbs/ft (203 N.m).

10.8 MONITORING PROGRAM(S)

. Stress Measurement

Several stress measurements made by CANMET indicate that the direction of the main stress is NNW-SSE. These measurements were taken between 1 200 and 1 850 feet deep (360 and 555 m).

In all cases studied, the minimal main stress was approximately vertical. The maximum main stress has no uniform direction and is almost indistinguishable from the intermediate principal stress. The two latter stresses are approximately horizontal and have a horizontal isotropic force field with some local variations. As mentionned in section 10.4, the "$\sigma h/\sigma v$" ratio ranges from 1.6 to 2: these results were obtained from "USBM" and "CSIR" cells.

On-site stress measurements vary as follows:
- Minimal principal stress : 2 120 - 3 870 psi (14.6 - 26.7 MPa)
- Intermediate principal stress : 2 410 - 4 970 psi (16.6 - 34.3 MPa)
- Maximum principal stress : 2 890 - 6 840 psi (19.9 - 47.2 MPa)

No stress measurements have been taken in the surface pillar or in the upper stopes.

. Displacement Measurement

Displacement measurement programs using extensometers have been introduced in several areas of the lower levels, particularly in the walls and the crown and rib pillars. In 1981, extensometers installed by the Company showed a convergence of 1/100 in (0.025 cm).

Monitoring stations have been located at the surface along an axis perpendicular to that of the deposit, in the open pit mine situated more to the west. These stations are 200 ft (60 m) apart over a total of 1 000 ft (300 m) in length. Monthly readings are taken and no movement has been detected to date.

. Other programs

CANMET also undertook two other programs. Sound velocity was measured on several occasions in the mine during the mining of pillars at the lower levels. Because of the mining sequence, velocity decreased slightly in the walls which had undergone a redistribution of stress. In general, the variations were less than 10% and overall the measurements indicated no general deterioration.

The microseismic program was also concentrated exclusively on the lower stopes. Interpretation of the readings, however, continues to be a problem; the origin and significance of sounds are difficult to determine or explain.

As mentionned in section 10.5, water pressure measurements were taken in the cavities encountered during mining. These readings were not taken systematically but only when drillers mentionned that the water pressure appeared high.

The upper stopes cannot be visually inspected as their access is blocked.

On the surface, at the extreme eastern part of the mine where a gradual cave-in occurred (Fig. 10.1), visual inspection is carried out once a month. However, no written report accompanies these visits.

10.9 SURFACE PILLAR DESIGN

. Personnel Involved

Surface pillar design is the responsability of the Engineering Supervisor and the Senior Planner. Next, the Mine Superintendent approves or modifies design plans. The Geology and the Mining Operations Departments are also consulted in the design process. Figure 10.4 shows the departments and persons involved in the process of pillar design in general.

In 1960, management awarded a mandate to an outside consultant for the dewatering of the lake covering part of the western zone of the deposit and for the study of the underlying oxidation zone.

Management has recently hired a consultant for ground control in the lower stopes.

. Pillar Dimensions

Surface pillar dimensions changed gradually with the advance of the undergorund and open pit operations. The present dimensions of the untouched parts of the pillar are given in Table 10.2.

ORGANIZATION CHART - PILLARS DESIGN

ORGANIGRAMME - CONCEPTION DES PILIERS

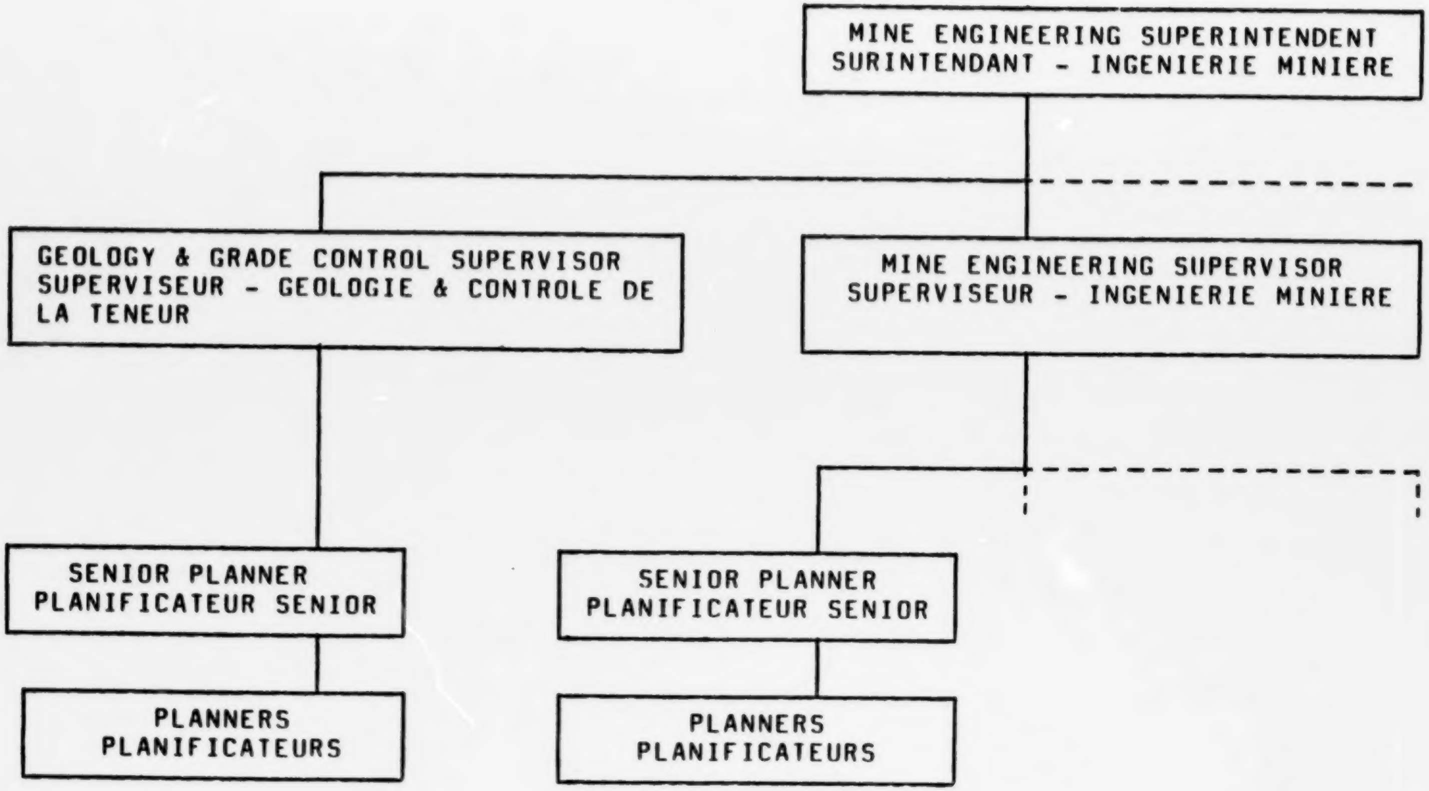

MINE ENGINEERING SUPERINTENDENT
SURINTENDANT - INGENIERIE MINIERE
GEOLOGY & GRADE CONTROL SUPERVISOR
SUPERVISEUR - GEOLOGIE & CONTROLE DE LA TENEUR
MINE ENGINEERING SUPERVISOR
SUPERVISEUR - INGENIERIE MINIERE
SENIOR PLANNER
PLANIFICATEUR SENIOR
PLANNERS
PLANIFICATEURS
SENIOR PLANNER
PLANIFICATEUR SENIOR
PLANNERS
PLANIFICATEURS

Figure 10.4

DIMENSIONS OF SURFACE CROWN PILLARS

DIMENSIONS DES PILIERS DE SURFACE

TABLE 10.2
TABLEAU 10.2

DIMENSIONS		PILLARS - PILIERS							
		# 1	# 2	# 3	# 4				
. THICKNESS: EPAISSEUR:									
- WATER BODY PLANS D'EAU	feet-pi. (m)	-	-	*	*				
- OVERBURDEN MORTS-TERRAINS	feet-pi. (m)	10-35 (3-11)	10-35 (3-11)	80 (24)	80 (24)				
. SURFACE CROWN PILLAR: PILIER DE SURFACE:									
- THICKNESS EPAISSEUR	feet-pi. (m)	150 (46)	150 (46)	150 (46)	120 (37)				
- WIDTH LARGEUR	feet-pi. (m)	50 (15)	45 (14)	220 (67)	100 (30)				
- LENGTH LONGUEUR	feet-pi. (m)	60 (18)	60 (18)	60 (18)	60 (18)				
- THICKNESS/WIDTH RATIO RAPPORT EPAISSEUR/LARGEUR		3,0	3,3	0,7	1,2				
. STOPE HEIGHT HAUTEUR DU CHANTIER	feet-pi. (m)	330 (101)	330 (101)	350 (107)	250 (76)				
. FILL HEIGHT HAUTEUR DU REMBLAI	feet-pi. (m)	0	0	0	0				

** dewatered lake - lac asséché

. Chronology

Management hoped to work the deposit right to the surface using the block caving method but, because of the poor behaviour of the rock mass which produced too much dilution, they changed to the open stope method with recovery by sub-levels without fill.

Part of the mine was exploited by two open pit mines (west and east of the deposit) and later 75% of the surface pillar was recovered by underground techniques. The areas of pillar left intact correspond to zones of weakness or to zones of poor tonnage or grade.

The recovery of the surface pillar was planned from the start of operations. In the oxidized part situated under the lake, management left a 150 ft thick (46 m) pillar as recommended by an outside consultant.

. Design Factors

The design of the surface pillar was based on the practical experience of the personnel involved and also on the recommendations of outside consultants. The reports of these consultants were not available, however.

Management specifies that the engineers involved in the surface pillar design based their approach on the formation of natural arches above the upper stopes.

10.10 VISUAL EVALUATION OF THE SURFACE PILLAR(S)

The drifts ending at the surface pillar have been blocked for several years. The visual evaluation of the surface pillar was therefore limited to areas accessible from the surface or within the limits of the old open pit mines.

The rock walls show a well-developed degree of fracturing and at least three families of joints are present in the hanging wall. The footwall is fairly massive. The joints intersect parallelipiped blocks of about one cubic foot. The joints do not seem to be filled with alteration material.

The two subparallel dykes crossing the central part of the deposit help support the hanging and footwalls.

Despite evident fracturing and a 70° dip, the hanging wall appears stable. The rock layers appear to be cemented together. The whole rock mass cut at the surface shows no humid or flooded zones. Hydrogeological conditions are controlled by the underground pumping systems.

The tailings dumped in the western part are partly leached by precipitation. Fine particles are washed farther along the surface to the extreme western part of the mine. The extreme eastern portion of the mine is covered with vegetaion. The caved-in area where the surface has fallen in by several feet can be distinguished from the access road leading to the "eastern" open pit mine.

10.11 MANAGEMENT'S COMMENTS

Management is of the opinion that research based on the computerized models of mining sequences will help increase safety in the stopes and raise productivity. Also, stress studies under way using triaxial cells will contribute to stope and pillar design.

The development and utilization of equipment to monitor wall and pillar deterioration would optimize mining operations.

MINE #11

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11.0 SUMMARY OF THE VISIT

The deposit is composed of veins of gold-bearing quartz enclosed in porphyric syenite. The principal vein strikes N65°E and shows a dip of 75° to 85° to the south-east.

The mine's infrastructures were built on a presque isle and during mining of the deposit, the lake ringing the infrastructures was gradually filled in with mine tailings.

The layers of soil (including the mine tailings) which presently cover the deposit are between 30 and 100 ft thick (9 and 30 m).

An initial surface pillar of 200 ft (60 m) was left by a first company that closed the mine in 1965. In 1983, a second company undertook the recovery of this pillar using a variant of the cut-and-fill method. Mine management followed an investigative program aimed at determining the nature of the soil covering the deposit and at tracing the precise topography of the surface at the soil-rock interface.

Four (4) upper stopes delimit four (4) surface pillars of an average thickness of 30 ft (9 m). The present thickness of the pillars equals about twice the width of the underlying stopes.

11.1 GENERAL INFORMATION

. Regional Geology

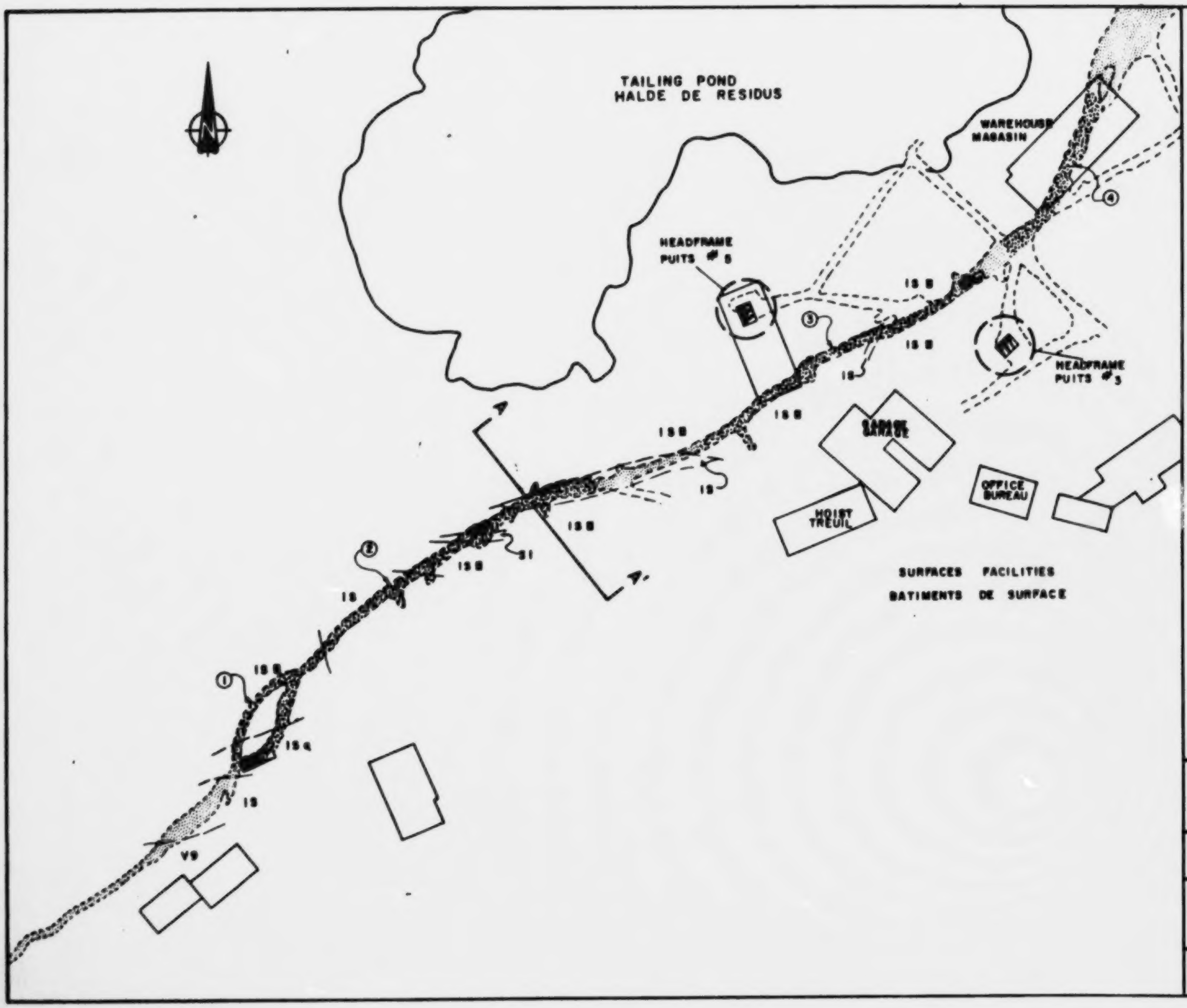
The region under study is part of the Superior Province and is characterized by a belt of Precambrian sedimentary rock composed of metamorphized tuff, a conglomerate and a grauwacke, situated in a major syncline striking WE and running more than 100 mi (160 km). In the orebody, the syncline undergoes a distorsion and strikes at about N60°E. A substantial intrusion of granite and syenite, located south of the sedimentary belt, is probably the cause of this change in direction. Numerous intrusions of syenite and lamprophyre and diabase dykes cut across the sedimentary rock. Metamorphic facies of green schist characterize the region.

. Local Geology

The walls are generally made of red porphyric syenite and formed of felsic syenite, comglomerate and tuff in places (figures 11.1 and 11.2). The ore is associated with major faults dipping abruptly. A system of parallel fractures, linked to these faults, causes rock fragments roughly resembling diamonds.

. Characteristics of the Deposit

The orebody is composed of veins and discontinuous lenses of gold-bearing quartz with fractures containing graphite, sulfide and molybdenite. The ore veins may be as long as 3½ mi (5.6 km). The main deposit has the following characteristics:


N
TAILING POND
HALDE DE RESIDUS
WAREHOUSE
MAGASIN
HEADFRAME
PUITS #5
HEADFRAME
PUITS #3
GARAGE
GARAGE
OFFICE
BUREAU
HOIST
TREUIL
SURFACES FACILITIES
BATIMENTS DE SURFACE
A
A'
15B
15B
15B
15B
15B
15B
15B
15
15
15
15
15a
S1
V9
①
②
③
④
LEGEND - LEGENDE
15a Felsic syenite
Syénite felsique
15B Porphyric syenite
Syénite porphyrique
S1 Conglomerate
Conglomérat
V9 Tuf
Tuff
Ore zone
Zone minéralisée
Stope
Chantier
0 50 100
feet - pieds

200 Level geology
Géologie niveau 200

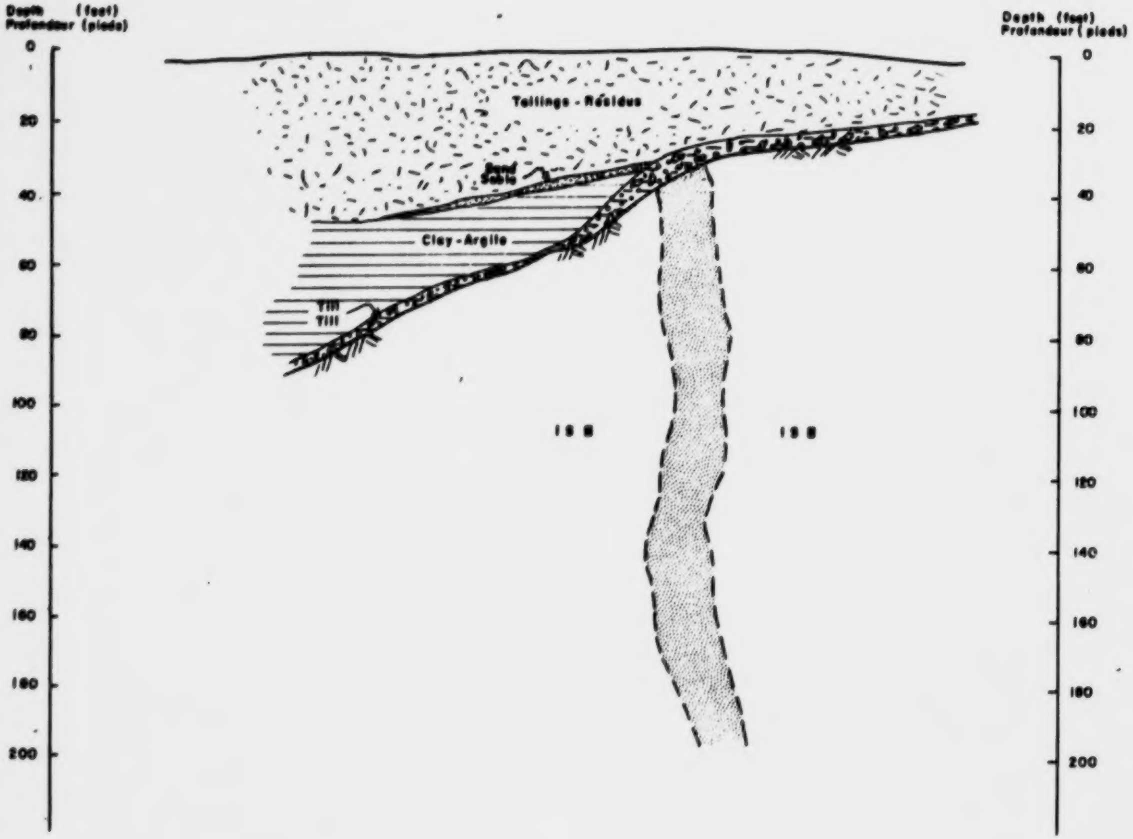
ROCHE

MINE #11 MINE

SURFACE PLAN
PLAN DE SURFACE

Date 07 / 85

Figure 11.1


Depth (feet)
Profondeur (pieds)
0
20
40
60
80
100
120
140
160
180
200
Tailings - Résidus
Sand
Sable
Clay - Argile
Till
Till
198
198

LEGEND - LEGENDE

198 Porphyric syenite
Syénite porphyrique

▨ Ore zone
Zone minéralisée

SECTION
COUPE A-A'

0 15 30
feet - pieds

ROCHE
associés ltée
Groupe conseil

[illegible]
Sainte-Foy, Québec
[illegible] Canada
[illegible]
Télex [illegible]

MINE #11 MINE

GEOLOGICAL SECTION
COUPE GEOLOGIQUE

Date	Figure
07/85	11.2

Length	Width	Depth
2 500 ft	3-20 ft	8 500 ft
(760 m)	(1-6 m)	(2 590 m)

The deposit strikes N65°E and dips 75° to 85° to the south-east. Daily production is currently about 500 tons. Production was continuous between 1913 and 1965; from 1966 to 1983, the mine ceased all operation and since then has been working on a continuous basis.

11.2 MINE ENVIRONMENT

Surface infrastructures, including a garage, are located near the surface pillars. These buildings are situated on a presque isle and as mining work progressed, the lake was filled with mine tailings.

No settlement has been observed on the surface since the beginning of operations.

Two mines are located in the vicinity of the mine visited.

11.3 OVERBURDEN

. Studies

In collaboration with an outside consultant, the Company undertook a works program aimed at determining the nature and thickness of the layers of soil, as well as the topography of the rock. This work was meant to optimize the recovery of the surface pillars and at the same time, determine the safety conditions at the surface. The degree of soil saturation and the liquefaction potential under the influence of a shock were among the characteristics studied.

The rock profile and the soil stratigraphy were determined from a seismic refraction reading and from holes drilled along the longitudinal axis of the deposit at an average distance of 100 ft (30 m) on both sides of this axis. The following research indicates the importance mine management attributes to surface conditions and shows the sources of basic information:

- 24 rotary drillings (using inverse circulation) to about 5 ft (1.5 m) into the rock;
- 7 drill holes, without samples, as far as the rock;
- 26 drill holes with soil samples as far as the rock and BX drilling into 10 ft (3 m) of rock;
- 49 soundings to the rock interface, in order to establish a base line directly over the longitudinal axis of the deposit;
- 35 (8 in: 20cm Ø) holes drilled from the surface for filling the stopes: these holes are spaced at 50 ft (15 m) intervals along the longitudinal axis of the deposit.

- about 70 diamond drilling test holes spread over the surface pillar zone;
- and finally, a seismic refraction reading including 25 lines spaced at about 200 ft (60 m) intervals and oriented perpendicular to the deposit. Each line contains 12 geophones 30 ft (9 m) apart, over a width of 330 ft (100 m).

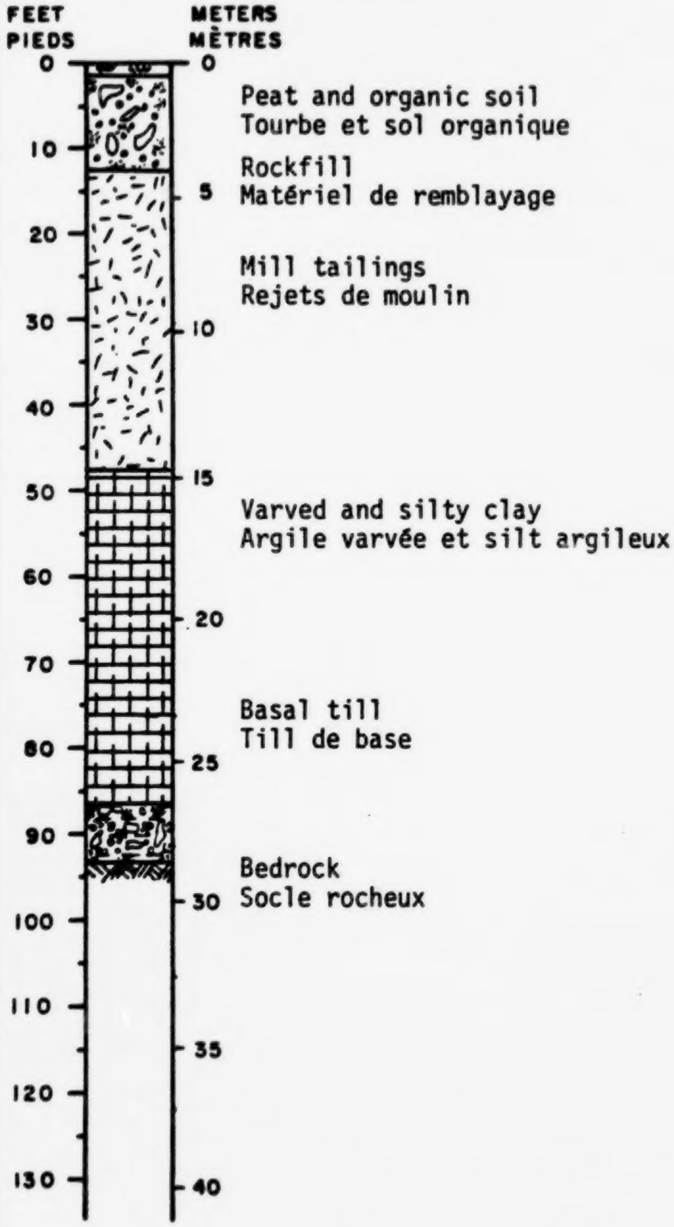
Stratigraphy and Characteristics

The rock profile and overburden stratigraphy vary considerably from east to west across the 2 500 ft (760 m) that cover the property. From Figure 11.2, one may conclude that, in general, the overburden is much thicker on the north side of the deposit.

The main components of the overburden, starting from the surface, are illustrated in Figure 11.3 and briefly described as follows:

	Average Thickness	Number SPT	Water Content
. Peat and organic soil	1.5 ft (0.5 m)	1-7	82-153
. Fill material: gravel, sand, boulders ...	11 ft (3.3 m)	3-9	-
. Mill tailings: thickness increases to the north	6-35 ft (1.8-11 m)	-	-
. Varved clay and silty clay: thickness increases in the north.	0-39 ft (0-12 m)	-	-

SOIL STRATIGRAPHY
STRATIGRAPHIE DU SOL


FEET
PIEDS
METERS
MÈTRES
0
10
20
30
40
50
60
70
80
90
100
110
120
130
0
5
10
15
20
25
30
35
40
Peat and organic soil
Tourbe et sol organique
Rockfill
Matériel de remblayage
Mill tailings
Rejets de moulin
Varved and silty clay
Argile varvée et silt argileux
Basal till
Till de base
Bedrock
Socle rocheux

ROCHE associés ltée Groupe-conseil 2535, boul Laurier, Sainte-Foy, Québec G1V 4M3 Canada (418) 871 9800 Télex : QBC 051 31583	**MINE # 11 MINE**	**Date** 07-1985	**Figure** 11.3

The clay appears to be preconsolidated in the top of the layer and the unit weight of the material varies between 115 and 120 lbs/ft^3 (18 and 19 KN/m^3).

Except for a fairly small area, the overburden has not been removed. It has not been drained eventhough a slight hydraulic gradient towards the upper stopes has been observed. The layer of clay, situated near the rock interface, seems to support a sheet of water above the surface pillars. The water lies about a foot (0.3 m) below the surface of the ground.

11.4 ROCK MASS

. Nature of the rock

Details of the rock mass are as follows:

Footwall : porphyric syenite
Deposit : vein of gold-bearing quartz
Hanging wall : porphyric syenite

A sericitization zone about 12 ft (3.6 m) thick surrounds the deposit. Near the wall/deposit contact points, the rock tends to become significantly altered, with veins of quartz and fracture zones showing chloritized surfaces, with graphite or sulfides.

. Structural Geology

A system of faults striking NS and NE-SW and minor fractures associated with this system have created a well developed pattern of joints in specific zones of the mine. No study has been conducted on joints in this mine; however, mine management mentions that the joints are most developed in the porphyric syenite.

No evaluation of the natural stress has been conducted in this mine.

. Characterestics

Very little testing has been conducted on the rock mass. The R.Q.D. value is generally less than 25%.

The areas of the rock mass where fracturing is pronounced are concentrated near the surface of the rock immediately inside the ore zone.

Point load tests were conducted on cores from thirteen (13) drill holes. The frequencey of these tests was one (1) per 10 ft (3 m) intervals. Table 11.1 shows the characteristics of the rock studied. The rock in the hanging wall seems to have a slightly higher compressive strength than the footwall.

There seem to be few concentrations of fractures or discontinuities along the ore zones of the faults and the diabase dykes. The R.Q.D. values generally correspond to the point load indices.

The quality of the rock mass is low to very low according to NGI, CSIR and modified CSIR classifications.

Depending on the classificaion used, the following results were obtained:
NGI : evaluation = 0.05 to 1.5
extremely poor to fair
CSIR, modified CSIR : very poor to fair

Some sound velocity tests gave the following results:
Upper zone (tailings) : 980 - 3 300 ft/s
(300 - 1 000 m/s)
Lower zone (clay) : 4 900 ft/s
(1 500 m/s)
Rock Mass : 11 500 - 19 700 ft/s
(3 500 - 6 005 m/s)

ROCK CHARACTERISTICS

CARACTÉRISTIQUES DE LA ROCHE

TABLE 11.1

TABLEAU 11.1

LOCATION EMPLACEMENT		FOOT WALL ÉPONTE INFÉRIEURE		OREBODY GISEMENT	HANGING WALL ÉPONTE SUPÉRIEURE				
ROCK TYPE TYPE DE ROCHE		Conglomerate Conglomérat	Red syenite porphyry Syénite porphyrique rouge	Gold bearing quartz veins Veines de quartz aurifères	Red syenite porphyry Syénite porphyrique rouge	Felsic syenite Syénite felsique	Basic syenite Syénite basique	Diabase Diabase	Tuff Tuf
DENSITY DENSITÉ		-	2,7	2,7	2,7	-	-	-	-
COMPRESSIVE STRENGTH RÉSISTANCE EN COMPRESSION	psi x 10^3 (MPa)	-	-	-	-	-	-	-	-
SHEAR STRENGTH RÉSISTANCE AU CISAILLEMENT	psi x 10^3 (MPa)	-	-	-	-	-	-	-	-
TENSILE STRENGTH RÉSISTANCE EN TENSION	psi x 10^3 (MPa)	-	-	-	-	-	-	-	-
POINT LOAD STRENGTH INDICE DE DOUBLE POINCONNEMENT	psi x 10^3 (MPa)	0,68 (4,7)	0,77 (5,3)	-	0,93 (6,4)	1,07 (7,4)	0,77 (5,3)	0,68 (4,7)	0,90 (6,2)
POISSON'S RATIO RAPPORT DE POISSON		-	-	-	-	-	-	-	-
YOUNG'S MODULUS MODULE DE YOUNG	psi x 10^6 (Gpa)	-	-	-	-	-	-	-	-
RQD %		≤ 25		≤ 25	≤ 25				
GEOMECHANICAL CLASSIFICATION CLASSIFICATION GÉOMÉCANIQUE	NGI CSIR et CSIR (mod)	0,05 - 1,5 voir texte							

11.5 HYDROGEOLOGICAL CONDITIONS

. Overburden

The hydrogeological conditions of the surface have been modified by the progressive filling of the lake with mine tailings. In all, thirteen (13) piezometers have been installed in the soil:

- Five (5) piezometers in the mine tailings; the depth of these soundings varies from 10 to 30 ft (3-9 m).
- Eight (8) piezometers in the sand and gravel; depth ranges from 30 to 68 ft (9-21 m).

As mentionned in section 11.3, the piezometric level holds at about one foot (0.3 m) below the surface of the soil.

. Rock Mass

No major infiltration has been observed in the mine. Drifts and stopes are dry to a depth of about 4 00 ft (120 m). No pumping is done in this mine; water is pumped from installations in one of the two mines in the vicinity of the one visited.

11.6 MINING OPERATIONS

. Mining Methods

Initially, the mine was worked by a first company to a depth of about 5 000 ft (1 200 m), between 1913 and 1965. Later, this company ceased all operation. After 1983, a second company took over the exploitation of the upper part of the mine, that is, a 200 ft (60 m) thick surface pillar left by the first company.

Recovery of the surface pillar is planned as follows:

- Cut-and-fill mining of the upper part of the deposit; i.e., from 30 ft (9m) below the soil/rock interface to a depth of about 200 ft (60 m).
- Development of four (4) upper stopes, which will, in fact, create four (4) surface pillars.

. Operating Conditions

Because of the proximity of the soil to the roofs of the planned upper stopes, a special mining method has been developed to increase the stability of the stopes. The extraction sequence in the stopes is as follows:

- Mining from the top towards the bottom.
- After mining of the first slice (8 ft - 2.4 m thick), a layer of sand is deposited at the bottom of the opening and poured from a pipe coming from the surface to form a slab 4 ft (1.2 m) thick, with a compressive strength of 3 000 psi (20 MPa). Before this operation, a plastic cover was placed over the sand, thus preventing the cement from mixing with the sand. The cement slab is anchored in the walls with steel

rebars (1½ in - 3.8 cm in diameter). Later, a sand-cement mixture (with a strength of 500 psi: 3.4 MPa after consolidation) is poured on the slab to complete the filling to the ceiling. During these operations, the pipe from the surface is lengthened as far as the ceiling of the second slice.

- Recovery of the second 8 ft (2.4 m) layer is facilitated by a bed of sand at the base of the first layer which cushions the shock of the blasting.
- More or less the same procedure is used in the recovery of the following layers.

The complete cycle for the recovery of a layer ranges from four (4) to five (5) weeks. The extraction rate is close to 90% and dilution may be as high as 30% from the waste coming from the walls.

11.7 SUPPORT AND REINFORCEMENT METHODS

. Primary Support

Three permanent rib pillars will separate the upper stopes at the end of the recovery of the initial surface pillar.

. Filling and Reinforcement

During exploitation of the surface pillars using the method described in section 11.6, support is maintained by casings cemented and filled with a mixture containing cement.

Conventional bolts 5 ft (1.5 m) long are installed primarily in the relatively unstable zones of the surface pillars. Wooden plates are installed under the bolt heads.

11.8 MONITORING PROGRAM(S)

. Stress Measurement

No stress measurements have been carried out in this mine.

. Displacement Measurement

No displacement measurements have been conducted at this mine.

. Other Programs

No particular program has been specially developped for the surface pillars, except for the following procedure. Three 22 ft (6.7 m) drill holes sloping 30° towards the top in relation to the horizontal have been bored in the direction of the roof of the next layer to be mined. These holes are used to locate major discontinuities which might greatly decrease the stability of the stopes.

11.9 SURFACE PILLAR DESIGN

. Personnel Involved

The persons and departments involved in the design of the surface pillars are indicated in Figure 11.4. The mine manager ratifies the sizing of the major pillars including the surface pillars.

The high content of gold in the surface pillar induced management to recover part of it and to leave rib pillars in the zones where content was lower.

The Company currently working the mine has, in the past, called in an outside consultant to optimize the recovery of the upper part of the deposit. The parameters studied by this consultant were:

- Major discontinuities
- Filling and reinforcement techniques
- Geostructural data for the evaluation of the rock mass: NGI, CSIR and modified CSIR geomechanical classifications were used.

From this basic data, the consultant recommended the bolting of the very fractured zones using bolts ranging from 3 to 6 ft (1 to 2 m) long, in a 3 x 3 ft (1 x 1 m) pattern, with steel mesh and, if necessary, oversized steel plates and/or shotcrete.

It was this same consultant who suggested the mining method described in section 11.6 .

ORGANIZATION CHART - PILLARS DESIGN
ORGANIGRAMME - CONCEPTION DES PILIERS

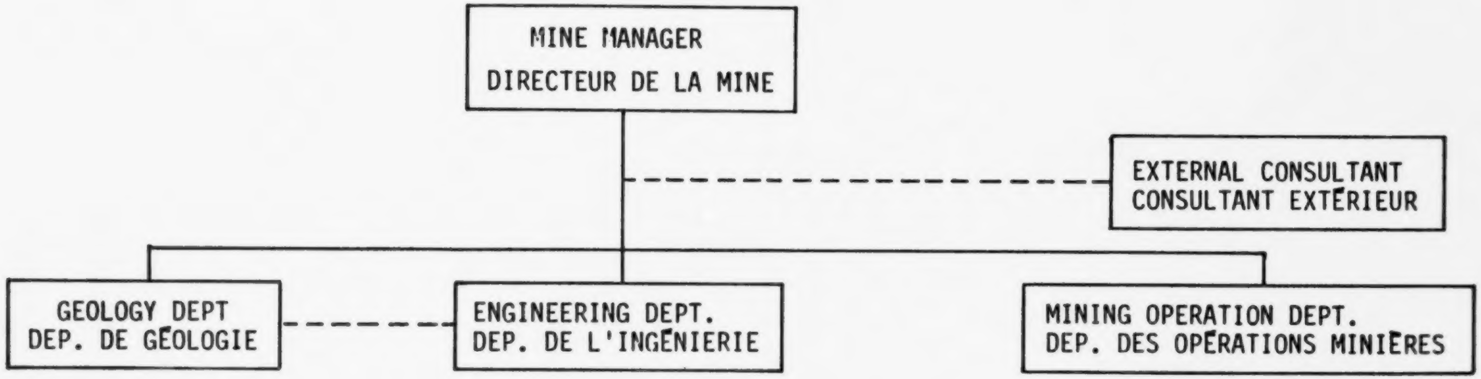

MINE MANAGER
DIRECTEUR DE LA MINE
EXTERNAL CONSULTANT
CONSULTANT EXTÉRIEUR
GEOLOGY DEPT
DEP. DE GÉOLOGIE
ENGINEERING DEPT.
DEP. DE L'INGÉNIERIE
MINING OPERATION DEPT.
DEP. DES OPÉRATIONS MINIÈRES

Figure 11.4

. Chronology

As mentionned in sections 11.1 and 11.6, mining of the upper part of the deposit was carried out in two independant phases:

- General mining of the deposit halting the stopes at about 200 ft (60 m) below the surface.
- Closing the mine between 1965 and 1983.
- Reopening and mining of the surface pillars (4 upper stopes) using a variant of the cut-and-fill method.

. Design Factors

The sizing of the surface pillars is based on an analysis of stress and on the state of the rock mass containing the upper stopes. However, the details of this study were not available. It may be noted that the dimensions of the stopes produce surface pillars of a thickness about equal to twice the width of the stopes.

. Pillar Dimensions

Table 11.2 shows the present dimensions of the surface pillars and the underlying stopes.

DIMENSIONS OF SURFACE CROWN PILLARS

DIMENSIONS DES PILIERS DE SURFACE

TABLE 11,2
TABLEAU 11,2

DIMENSIONS		PILLARS - PILIERS							
		#1	#2	#3	#4				
. THICKNESS: EPAISSEUR:									
- WATER BODY PLANS D'EAU	feet-pi. (m)	-	-	-	-				
- OVERBURDEN MORTS-TERRAINS	feet-pi. (m)	40 (12)	60 (18)	40 (12)	60 (18)				
. SURFACE CROWN PILLAR: PILIER DE SURFACE:									
- THICKNESS EPAISSEUR	feet-pi. (m)	40 (12)	20 (6)	30 (9)	25 (8)				
- WIDTH LARGEUR	feet-pi. (m)	20 (6)	10 (3)	10 (3)	20 (6)				
- LENGTH LONGUEUR	feet-pi. (m)	100 (30)	340 (104)	300 (91)	230 (70)				
- THICKNESS/WIDTH RATIO RAPPORT EPAISSEUR/LARGEUR		2	2	3	1,3				
. STOPE HEIGHT HAUTEUR DU CHANTIER	feet-pi. (m)	80 (24)	80 (24)	80 (24)	80 (24)				
. FILL HEIGHT HAUTEUR DU REMBLAI	feet-pi. (m)	80 (24)	80 (24)	80 (24)	80 (24)				

11.10 VISUAL EVALUATION OF THE SURFACE PILLAR(S)

The most interesting aspect of the underground visit was, without a doubt, the efficiency of the artificial supports installed. In spite of the relatively high degree of strength of the rock contact (approximately 22 000 psi or 154 MPa), the rock mass is highly jointed and the blocks have a tendancy of sliding onto one another. The average RQD value at the contact point with the ore zone varies around 30%. The pronounced deterioration of the walls in many of the access drifts is quite noticeable, but conventional bolting (3 x 3 ft or 1 x 1 m) seems to be sufficient to prevent falling blocks. Finally, the installation of horizontal, artificial, concrete pillars is highly efficient in assuring the stability of the walls by reducing the unsupported height of the stopes.

11.11 MANAGEMENT'S COMMENTS

The mine's management feels that the experience acquired during the various mining operations on the surface pillars should be written up and compiled in a reference book.

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12.0 SUMMARY OF THE VISIT

This property is located across the axis of a local anticline. Competent volcanic rock is found all over the ore zone. The deposit consists of massive sulfides (Cu, Zn) and measures 800 ft (240 m) long by 400 ft (120 m) wide. It is sub-vertical and plunges at 25-30° to the NW.

Along half of its length to a depth of 450 ft (137 m) it has been worked by an open pit mine. The NW portion dips beneath a layer of andesite which forms the present surface pillar. This is covered with 25 to 75 ft (7.6 to 23 m) of overburden composed mainly of clay.

The blasthole mining method with hydraulic fill (uncemented) has been used since the start of operations to work the primary stopes. The Company is currently finishing the recovery of the pillars working back towards the mine shaft.

Part of the andesite section gave way shortly after the drawing of the last rib pillar and liquid clay infiltrated the broken rock of several stopes. It stabilized, however, when it became mixed with sand from neighbouring stopes and with blasted ore.

A later analysis of the situation led to the conclusion that it was possible to continue the extraction in the upper part of the deposit by continually adding fill at the surface so that it runs down into the underlying stopes. This operation is much like the sub-level caving method.

The remaining surface pillar, unaffected by the initial rupture, is probably still in place.

12.1 GENERAL INFORMATION

. Regional Geology

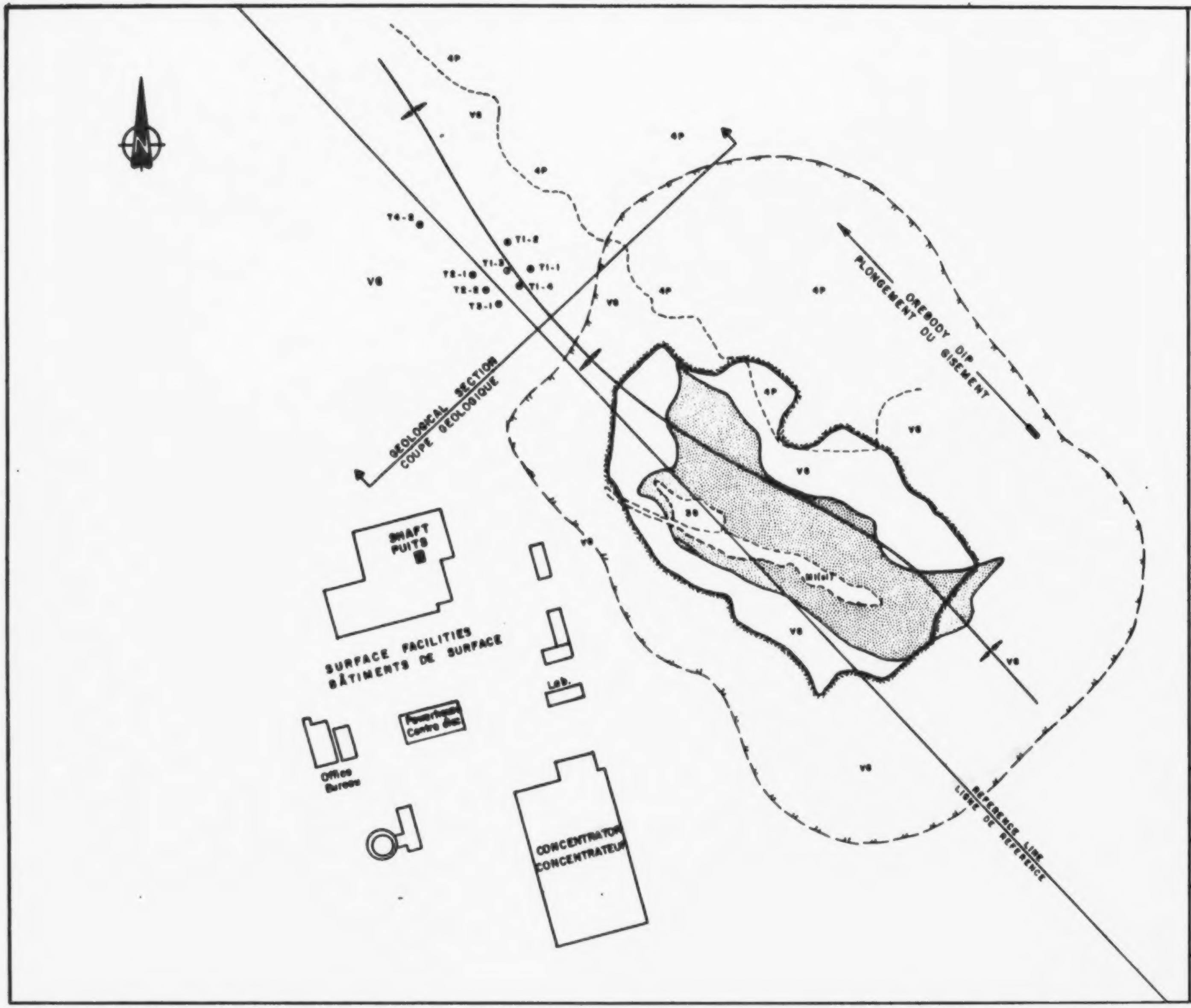
The property is located in the southern part of the Superior Province, in a region characterized by a substantial anticline plunging to the west. Formations of gabbro and anorthosite already in place before the deformation occupy the center of the anticline. The mine is on the southern flank of the anticline, composed of volcanic rocks with rhyolite at the base topped by andesite. These two formations are separated by a band ranging from 2 to 10 ft (0.6 to 3 m) thick of metapyroclastic rocks and/or metasediment known as "key-tuffite". This band indicates the ore zone. The trace of the lava schistosity is parallel to the main axis of the regional complex (see Figure 12.1).

. Local Geology

The deposit is located in the axis of a second, less substantial anticline, (plunging to the NW). The dip of the rock units is about 40-45° SW. The position of each of the formations is visible in Figure 12.2 as is the mounding of the upper area of the rock units where the deposit is located.

. Characteristics of the Deposit

The ore zone is 60 to 70% massive sulfides: the economic minerals are copper and nickel. The presence of this stratiform layer is proof of the volcanogenic origin of the orebody. However, following a


N
GEOLOGICAL SECTION
COUPE GEOLOGIQUE
OREBODY DIP
PLONGEMENT DU GISEMENT
REFERENCE LINE
LIGNE DE REFERENCE
T4-2
T1-2
T1-3
T1-1
T1-4
T2-1
T2-2
T3-1
V6
4P
3B
MI(cl)
SHAFT
PUITS
SURFACE FACILITIES
BÂTIMENTS DE SURFACE
Lab.
Powerhouse
Centre élec.
Office
Bureau
CONCENTRATOR
CONCENTRATEUR

LEGEND-LEGENDE

▨	Massive sulphide at surface Sulfure massif en surface
MI(cl)	Schist, talc and chlorite rock Roche a talc, chlorite et schiste
3B	Gabbro
V6	Andesite Andésite
4P	Peridotite Péridotite
━	Pit limit Limite de la fosse
┴	Overburden stripping limit Limite d'enlèvement de mort-terrain
✕	Anticline Anticlinal
● T2-1	Drilling Sondage

0 100 200
feet-pieds

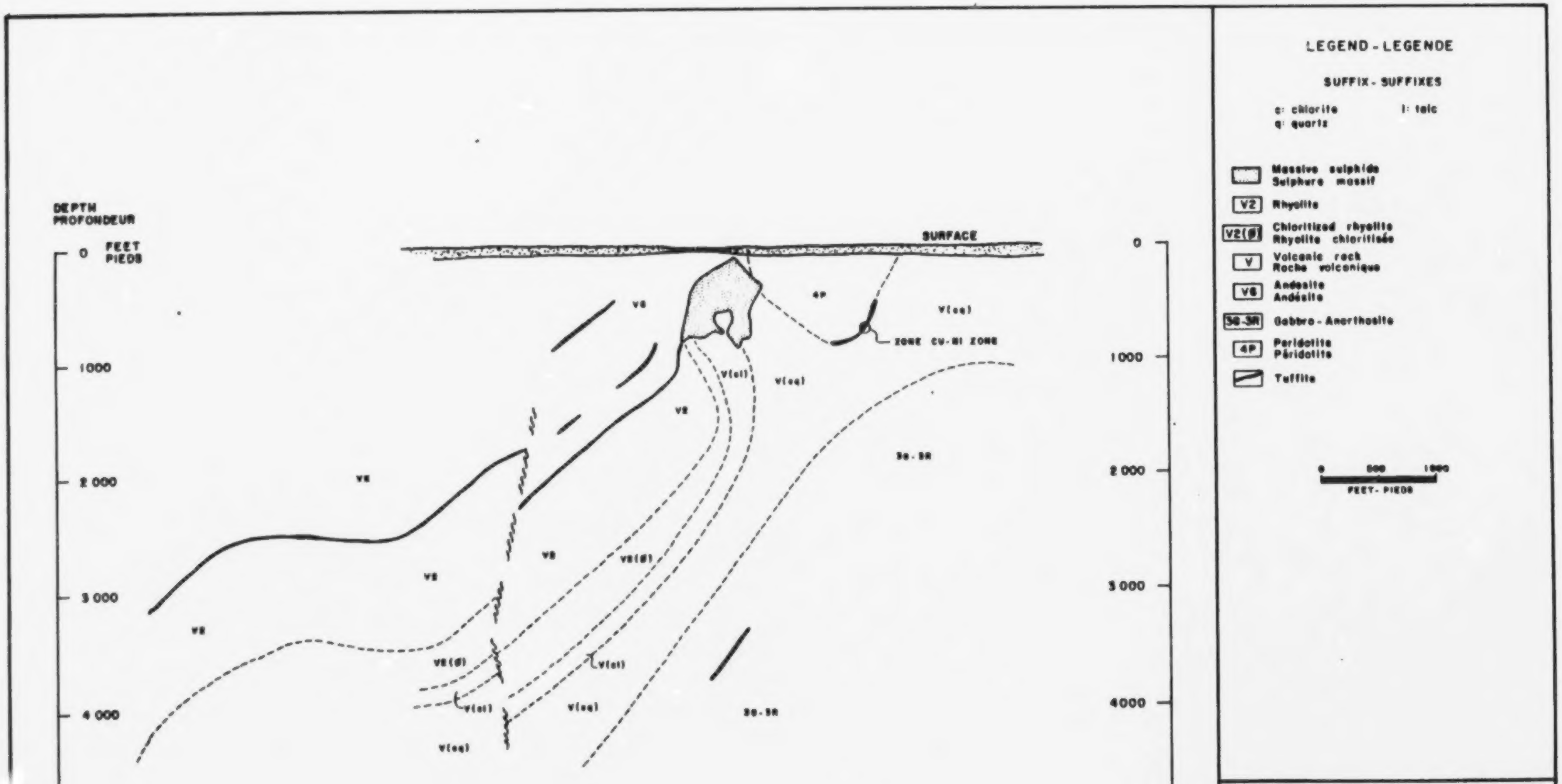
ROCHE
associés ltée
Groupe conseil

2535 boul. Laurier
Sainte-Foy, Québec
G1V [illegible] Canada
(418) 871 [illegible]
Telex (Q) 051 31980

MINE #12 MINE

SURFACE PLAN
PLAN DE SURFACE

Date	Figure
08/85	12.1


DEPTH
PROFONDEUR
0 FEET PIEDS
1000
2 000
3 000
4 000
SURFACE
4P
V(cq)
ZONE CU-NI ZONE
V6
V2
V(cl)
V(cq)
3G-3R
V2(Ø)
V(cl)
V(cq)
3G-3R
0
1000
2 000
3 000
4000
LEGEND - LEGENDE
SUFFIX - SUFFIXES
c: chlorite
q: quartz
l: talc
Massive sulphide
Sulphure massif
V2 Rhyolite
V2(Ø) Chloritized rhyolite
Rhyolite chloritisée
V Volcanic rock
Roche volcanique
V6 Andesite
Andésite
3G-3R Gabbro - Anorthosite
4P Peridotite
Péridotite
Tuffite
0 500 1000
FEET - PIEDS

ROCHE
Groupe conseil

2535 boul Laurier
Sainte-Foy Québec
G1V 4M3 Canada

MINE #12 MINE

GEOLOGICAL SECTION
COUPE GEOLOGIQUE

Date	Figure
08/85	12.2

complicated series of foldings, the sulfide layer was twisted back on itself to become the nucleus of the deposit, massive in shape and striking NW-SE parallel to the axis of the local anticline.

The south-east part of the deposit which rose almost to the surface was worked with an open pit mine to a depth of about 450 ft (135 m). Later, the underground stopes were lengthened as far as the bottom of the open pit mine. The NW part of the deposit, which is of particular interest to this study, plundges 25 to 30° to the NW. The approximate overall dimensions of the deposit are thus:

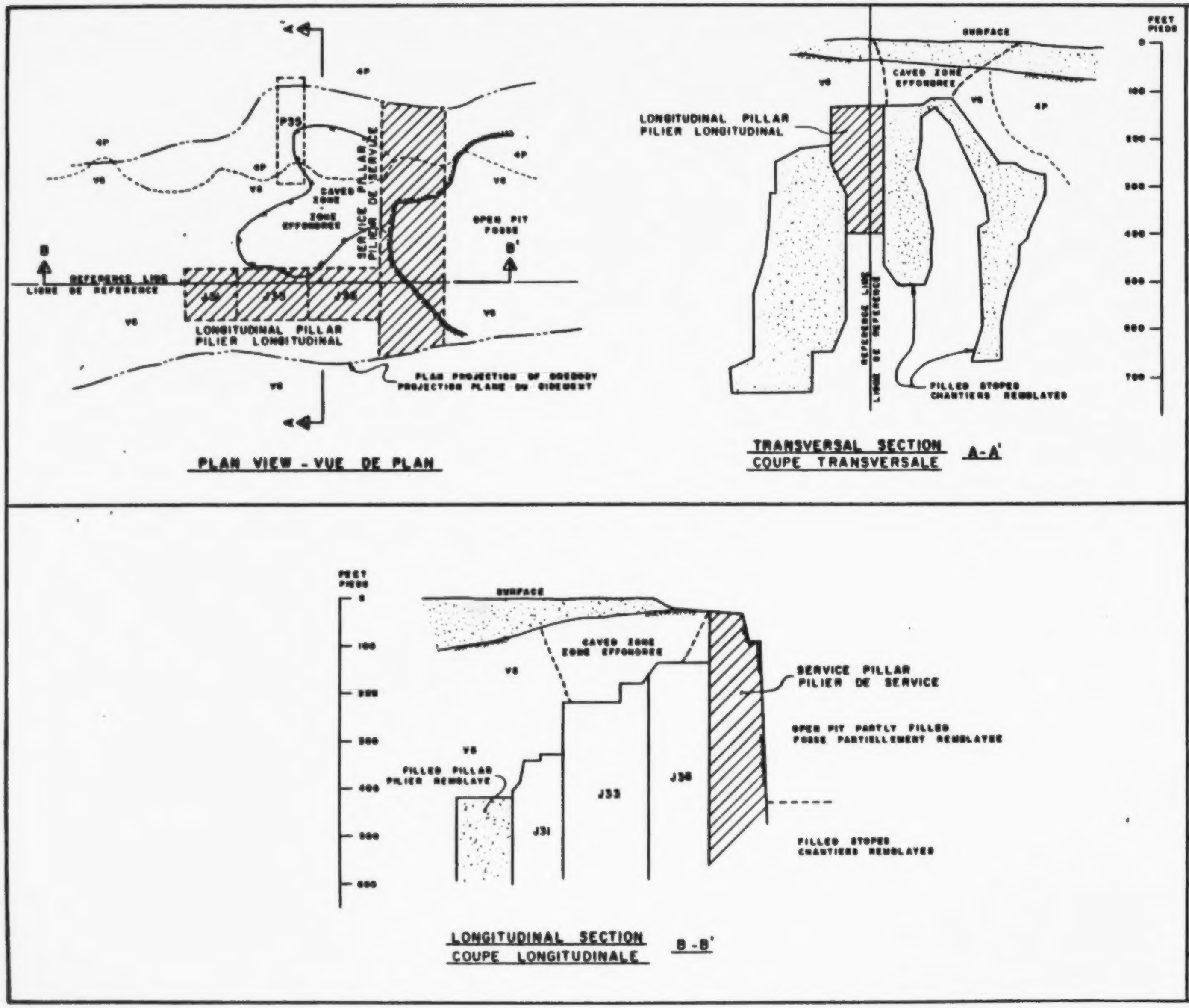
Length	Width	Depth
800 ft	400 ft	1 000 ft
(240 m)	(120 m)	(300 m)

The dip is close to vertical and the upper portion is domeshaped and plunges NW. Production is continuous at about 2 300 tons per day on a six-day week basis.

From the sketch in Figure 12.3 attached, it is possible to visualize the configuration of the study zone and the geometry of the problem as it stood before the cave-in of the andesite dome.

In this case history, the notion of a surface pillar does not apply to individual stopes. One must rather consider the whole of the upper portion of the deposit.

Finally, it should be noted that almost all of the underground mine has now been filled and that the Company is completing recovery of the pillars.


B
B'
A
A'
REFERENCE LINE
LIGNE DE REFERENCE
P35
J31
J33
J36
CAVED ZONE
ZONE EFFONDREE
SERVICE PILLAR
PILIER DE SERVICE
OPEN PIT
FOSSE
LONGITUDINAL PILLAR
PILIER LONGITUDINAL
PLAN PROJECTION OF OREBODY
PROJECTION PLANE DU GISEMENT
4P
V6
SURFACE
FEET
PIEDS
0
100
200
300
400
500
600
700
FILLED STOPES
CHANTIERS REMBLAYES
OPEN PIT PARTLY FILLED
FOSSE PARTIELLEMENT REMBLAYEE
FILLED PILLAR
PILIER REMBLAYE

PLAN VIEW - VUE DE PLAN

TRANSVERSAL SECTION
COUPE TRANSVERSALE A-A'

LONGITUDINAL SECTION
COUPE LONGITUDINALE B-B'

LEGEND-LEGENDE

V6	Andesite Andésite
4P	Peridotite Péridotite

0 100 200
FEET-PIEDS

ROCHE

MINE # 12 MINE

GEOMETRY OF PILLARS
GEOMETRIE DES PILIERS

Date	Figure
08/85	12.3

12.2 MINING ENVIRONMENT

The property is isolated from any other excavation at the deposit level. Along the longitudinal axis, the along south-east portion has been completely worked right to the surface and filled in over the surface pillar area where some mine tailings and 26 to 76 ft (7.8 to 22.8 m) of overburden are to be found.

There has been some sinking on the surface caused by the surface pillar cave-in. The chronological steps leading up to this situation will be discussed further along.

Some large buildings, like the concentrator, the head frame, etc., are located to the south side of the shaft and deserve particular attention, although they are situated in the andesite formation which is generally of good competence.

12.3 OVERBURDEN

. Studies

Because of the particular shape of the deposit, several diamond drillings were carried out directly over the surface pillar. From the quantity of information available, a map was drawn up showing the elevation curves of the rock base at intervals of 10 ft (3 m) thus allowing a definition of the thickness of the overburden. Aside from this data, a geotechnical study was conducted in this same zone, including the following experiments:

T1: Four (4) drill holes without samples to the rock base.

T2: Two (2) drill holes with samples of the overburden; determination of the scissometric profiles and coring in the rock.

T3: One (1) observation drill holes of the soil and coring to a depth of 75 ft (23 m) into the rock, without samples.

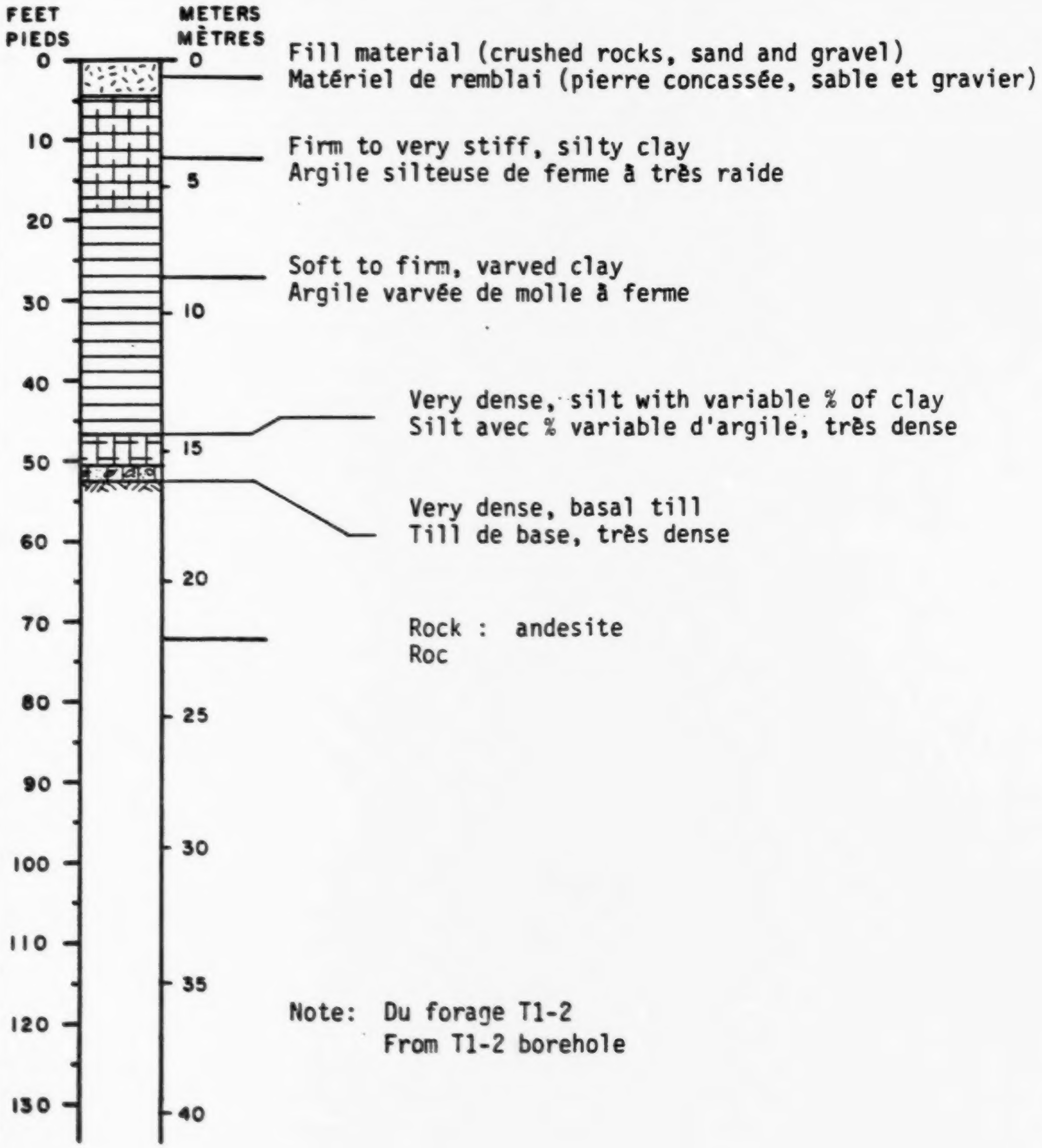
T4: Two (2) drill holes with complete sampling to the rock scissometric profiles, two "in situ" permeability tests and installation of piezometers.

The location of these experiments is shown in Figure 12.1 previously presented.

. Stratigraphy and characteristics

The soils covering the surface pillar area are mostly composed of till and clay. Figure 12.4 shows a typical stratigraphic section and the mechanical characteristics of these soils are shown in Table 12.1. Briefly,

SOIL STRATIGRAPHY
STRATIGRAPHIE DU SOL


FEET
PIEDS
METERS
MÈTRES
0
10
20
30
40
50
60
70
80
90
100
110
120
130
0
5
10
15
20
25
30
35
40
Fill material (crushed rocks, sand and gravel)
Matériel de remblai (pierre concassée, sable et gravier)
Firm to very stiff, silty clay
Argile silteuse de ferme à très raide
Soft to firm, varved clay
Argile varvée de molle à ferme
Very dense, silt with variable % of clay
Silt avec % variable d'argile, très dense
Very dense, basal till
Till de base, très dense
Rock : andesite
Roc

Note: Du forage T1-2
From T1-2 borehole

ROCHE associés ltée Groupe-conseil 2535, boul Laurier, Sainte-Foy, Québec G1V 4M3 Canada (418) 871 9600 Télex: QBC 051 31583	**MINE # 12 MINE**	Date 07-1985	Figure 12.4

SOILS CHARACTERISTICS

CARACTÉRISTIQUES DES SOLS

TABLE: 12.1
TABLEAU: 12.1

PARAMETERS PARAMÈTRES		CLAY ARGILE	VARVED CLAY ARGILE VARVÉE	SILT SILT	SAND, GRAVEL SABLE GRAVIER	
UNIT WEIGHT POIDS VOLUMIQUE	lb/ft^3 (kN/m^3)	-	-	121 (19)	166 (26)	
LIQUID LIMIT LIMITE DE LIQUIDITÉ	%	54-65	59	-	-	
PLASTIC LIMIT LIMITE DE PLASTICITÉ	%	19-26	27	-	-	
WATER CONTENT TENEUR EN EAU	%	35-65	55-61	-	6.6	
APPARENT COHESION COHÉSION APPARENTE	lb/ft^2 (kN/m^2)	2465-522 (118-25)	1211-313 (58-15)	-	-	
EFFECTIVE COHESION COHÉSION EFFECTIVE	lb/ft^2 (kN/m^2)	-	-	-	-	
APPARENT ANGLE OF FRICTION ANGLE DE FROTTEMENT APPARENT		-	-	-	-	
SPT BLOW COUNT NOMBRE DE COUPS SPT		-	-	44-51	38-100	
COEFFICIENT OF PERMEABILITY COEFFICIENT DE PERMÉABILITÉ	cm/s	10^{-5}-10^{-6}	10^{-7}	3.9×10^{-4}	2.7×10^{-3}	
SENSITIVITY SENSIBILITÉ		5-10	6-13	-	-	

we are looking at a substantial deposit of lacustrian clay of low mechanical strength that is highly compressible. The clay is very hard at the surface (subject to drying out and to oxidation) and is highly plastic; deeper, it becomes softer.

The author of this study concludes that the main points to be considered concerning the grey varved clay are that it is practically impermeable, very easily re-shaped and of soft consistency. It is an important material to be considered in any study of the surface pillars. The study (very well structured) also gives an analytical summary of the liquefaction potential of each of the soils present at the surface, as shown in Figure 12.5.

As shown in Figure 12.1, all of the soils originally covering the open pit mine have been stripped; a slope of 1.5 was left at the edge of the crest of the excavation. Soils in the NW sector have not been touched except over the caved-in zone as will be described later in this text.

FIGURE 12.5

Type of soil	Discussion	Liquefaction Potential, as of April 1982
Glacial Till	In drilling T4#2, the till shows fine grains and is located beneath the water table. These two conditions can lead to liquefaction. However, the deposit is very dense making it less likely to become liquified.	Poor to nil
Sand and gravel	The deposit of sand and gravel in T4#1 is fairly coarse, dense to very dense and is above the water table. It should not become liquefied. However, it allows drainage which could allow considerable water intake.	Poor
Silt	The deposit of silt is fine. But it is above the water table and is dense. Despite the favorable ground conditions, it is nonetheless essentially non-plastic and consequently very water erodible.	Fair to poor
Clay	The clay desposit is problematic because of its low permeability. Though it is above the water table, its water content is high, especially in the grey clay. This, combined with the high sensitivity of the clay (ST 10), makes the soil very unstable when reshaped. It follows that the soil will tend to turn into a liquid or viscous mud when moved (earthquake, blasting etc.). The phenomenon is more easily seen in the grey clay than in the brown. The following are few additional indices of a clay that is very sensitive to reshaping. $W \geq WL$ $IL \geq 1.0$	High (grey clay) Fair (brown clay)

12.4 ROCK MASS

. Nature of the Rock

In the upper part of the deposit, only the most recent volcanic rocks are to be found, i.e. those resulting from the last phases of activity of the Archean period. Ore is confined beneath the andesite horizon which makes up both the hanging wall and the surface pillar. To the north, the footwall is composed of peridotite, with occasionnal intrusions or dykes or gabbro, rhyolite and diabase. The ore, as previously indicated, is composed of finely bedded massive sulfides.

All the formations situated south of the deposit underwent very slight metamorphism, in general, chloratization. However, below the ore dome where the flexion of the formations was excessive, the rhyolite units are highly chloritized, fragmented and chalky.

. Structural Geology

No simple interpretation of the structure was available at the mine. It is understandable that the dimensions of this deposit make such a description impossible. It should, however, be noted that the network of fractures linked with the tectonic phases is an important factor in the control of the mineralization. The principal network of fractures and faults strikes parallel to the axis of the local fold, that is EW, but is not continuous. The peridotite intrusion situated on the north flank of the deposit has also caused a second fracture network running NS.

. Characteristics

There is no quantitative data on the geomechanical properties of the rocks present at the upper levels of the mine. Generally, the andesite which forms the hanging wall and covers the sulfide is competent. No R.Q.D. measurement or classification has been used at this mine. The average density of the principal rock types is as follows:

Rhyolite	2.50
Andesite	2.66
Gabbro	2.98
Peridotite	3.00
Sulfide	3.55

An important characteristic to note is the cleanness of the contacts between the ore and the rock walls. The latter shows only a slight degree of chloritization and the host rock is relatively unaffected. In the same line of thought, it appears that the andesite originates from a period posterior to the mineralization and has remained much "fresher" than the formations located at the center or beneath the deposit (see Figure 12.1).

12.5 HYDROGEOLOGICAL CONDITIONS

. Overburden

A series of four (4) holes was used for the installation of conventional open piezometers. Two (2) of these were installed at the clay level, the other two at the soil/rock interface. These piezometers indicate that the level of the water table is situated either at the rock interface or in the glacial till at the base. This level was established approximately across the longitudinal axis of the deposit. On the other hand, further to the south, the piezometers indicate no more water (see Figure 12.1).

It appears therefore that water is not a major problem at this mine. An internal report indicates that considering, among other things, the slight thickness of the layers of till and silt (even if these layers can be drained), no investment is necessary in this area.

. Rock Mass

The pumping rate of this operation is relatively low considering the expanse of the stopes. Water is evacuated at a rate of 210 to 250 (I) GPM (16 to 19 L/s) including seasonal variations. The rock has few open fractures likely to carry water. From the beginning of operations, the Company has used shot packing to successfully close fissures; the mine has thus always been relatively dry, considering the wide use of hydraulic fill.

12.6 MINING OPERATIONS

. Mining Method(s)

The deposit is worked using the blasthole, post-fill method. In general, hydraulic fill is used except in some of the upper stopes of the mine where "dry" fill (sand) has been used. Stopes are mined transversally across the main axis of the deposit. They are 60 ft (18 m) wide, 300 to 400 ft high (90 to 120 m) and 60 to 100 ft long (18 to 30 m).

. Operation Conditions

In an initial phase, mining was generally conducted from the top to the bottom of the ore zone. Rib pillars 60 ft (18 m) wide were left between each primary stope, combined in the western sector of the deposit with a longitudinal pillar of 110 ft (33 m) and a service pillar of 130 ft (39 m). Figure 12.3 is a sketch of the configuration of this arrangement. The Company is presently completing the recovery of the pillars and is aiming for 100% ore recuperation. It should be noted that there was little dilution from the walls, but presently a certain percentage of fill is inevitably mixed with the ore. The primary stopes were drilled from the sub-levels spaced at about 70 ft (21 m), using 2 in (5 cm) holes.

The pillars, on the other hand, were blasted using 4 in (10 cm) holes, drilled in a 4.5 ft (1.4 m) pattern (load) by 12 ft (3.6 m) (spacing). The operators use an average powder factor of 0.4 lbs/ton (0.18 kg/t) and a maximum charge of 13 000 lbs (5 900 kg) of explosives per delay.

12.7 SUPPORT AND REINFORCEMENT METHODS

. Primary Support

At the beginning of operations, pillars were left to insure the stability of the roof and the walls as illustrated in the previous chapter. After the recovery of the latter, the walls were stabilized by the redistribution of stress and the use of hydraulic fill.

Generally speaking, the Company has had no stability problems except, as seen further on, with the surface pillar.

. Filling and Reinforcement

The fill used is composed exclusively of classified mill tailings (to eliminate the fines) and is pumped underground to a density that is 70% solid (% weight). Installation capacity is approximately 350 tons/hour.

Locally, the Company uses 5 ft (1.5 m) conventional bolts in the walls and 7 ft (2.1 m) bolts in the roof, following a 4 x 4 ft (1.2 x 1.2 m) pattern. In the haulage drifts, grouted cables 10 to 20 ft long (3 to 6 m) are frequently used at a rate of 7 units to 8 ft (2.4 m) of drift.

12.8 MONITORING PROGRAMS

. Stress Measurements

This type of measurement has not been effectuated at this mine.

. Displacement Measurement

Displacement measurements were taken at the surface section (or the thinnest part of the surface pillars). The aim of this testing was to verify the scope and magnitude of the subsidence. The system used was the laying, at intervals, of grouted rebars. The rebars were located NW of the deposit around the caved-in area.

. Other Programs

No other program of interest to this study was in effect.

12.9 SURFACE PILLAR DESIGN

. Personnel Involved

In this particular case, the design of the surface pillar is linked to the mining of the deposit, as the upper limit of extraction is fixed by the geometry of the deposit. Those responsible for the design are indicated in Figure 12.6. The work is done in close collaboration between the three (3) divisions: Mining, Engineering and Geology.

As far as we know, a first evaluation study of the soils and the water table situated above the surface pillar was conducted by an outside firm. A second study investigated the behaviour of the clays which infiltrated the stopes (after the cave-in of part of the surface pillar) and the corrective measures necessary to prevent or minimize a second infiltration or the progression of the first. Later, an internal study synthesized these evaluations and proposed a mining method using a longitudinal pillar.

. Chronology

The stability of the andesite crown making up the surface pillar is, in our opinion, much more linked to the mining sequence used in the underlying stopes than to problems of tectonic stress of major areas of poor terrain.

In order to describe clearly and precisely the evolution of the situation, there follows a list of events

ORGANIZATION CHART - PILLARS DESIGN
ORGANIGRAMME - CONCEPTION DES PILIERS

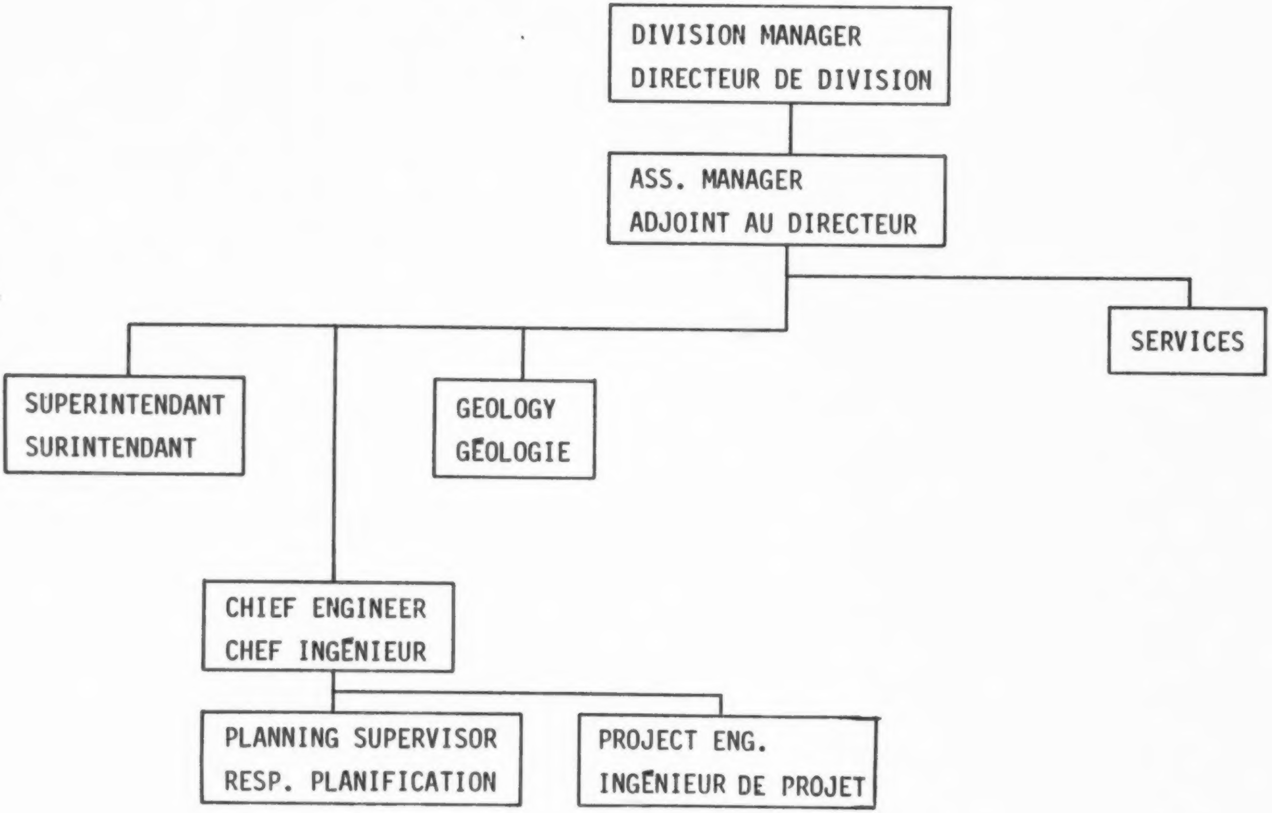
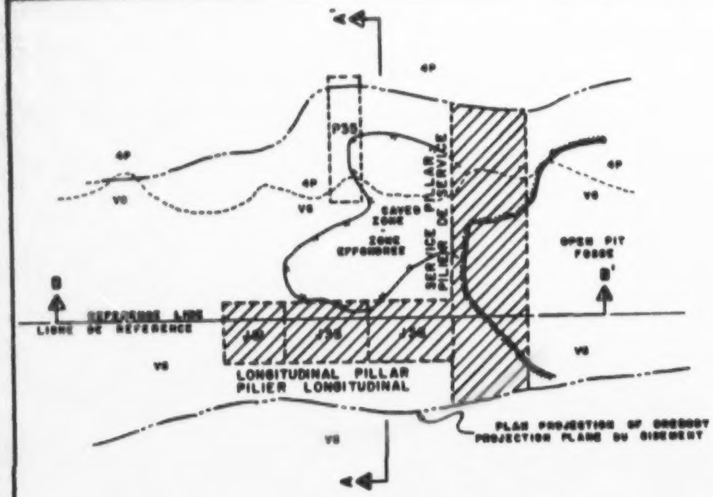

DIVISION MANAGER
DIRECTEUR DE DIVISION
ASS. MANAGER
ADJOINT AU DIRECTEUR
SERVICES
SUPERINTENDANT
SURINTENDANT
GEOLOGY
GÉOLOGIE
CHIEF ENGINEER
CHEF INGÉNIEUR
PLANNING SUPERVISOR
RESP. PLANIFICATION
PROJECT ENG.
INGÉNIEUR DE PROJET

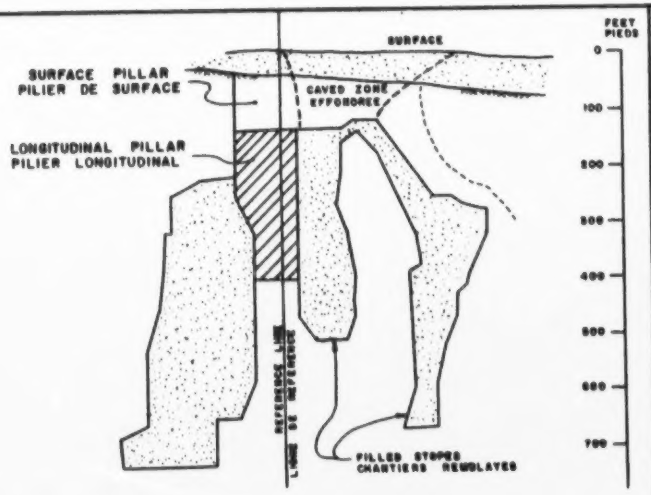
FIG. 12.6

which took place in the upper western sector of the property, using Figure 12.7 as a reference. In cross-section, the surface pillar has a triangular shape, some 410 ft (125 m) long and from 110 to 260 ft thick (33 to 79 m). Its width, on a plane view, corresponds to the narrowest part of the ore zone, that is about 300 ft (91 m). This volume of rock will be progressively sub-excavated as follows:

1) Mining of the primary stopes, 60 ft (18 m) wide, alternating with rib pillars also 60 ft (18 m) wide. All of the ore zone is excavated to the ore/waste limit, with the exception of a longitudinal pillar 110 ft (33 m) wide and the transverse service pillar 130 ft (39 m) wide.
2) Filling of the primary stopes with non-cemented classified tailings.
3) Open pit mining of the eastern sector of the property. At this side, the crown is detached from the surrounding mass. However, this sector is completely filled; the fill leans against the surface pillar.
4) Progressive recovery of the transverse pillars. Service pillar "H" is expected to be mined last, preceeded by the longitudinal pillar.
5) At a certain point, the andesite crown is supported only by the longitudinal pillar to the south, by the service pillar to the east and by the P-35 transverse pillar. The blasting of this latter pillar will bring down the thinnest part of the rock crown.
6) Re-evaluation of the situation and adoption of corrective measures.


B
REFERENCE LINE
LIGNE DE REFERENCE
P30
4P
V6
CAVED ZONE
ZONE EFFONDREE
SERVICE PILLAR
PILIER DE SERVICE
OPEN PIT
FOSSE
B'
LONGITUDINAL PILLAR
PILIER LONGITUDINAL
PLAN PROJECTION OF OREBODY
PROJECTION PLANE DU GISEMENT
A
A'

PLAN VIEW - VUE DE PLAN


SURFACE
FEET
PIEDS
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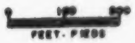
100
200
300
400
500
600
700
SURFACE PILLAR
PILIER DE SURFACE
CAVED ZONE
EFFONDREE
LONGITUDINAL PILLAR
PILIER LONGITUDINAL
REFERENCE LINE
LIGNE DE REFERENCE
FILLED STOPES
CHANTIERS REMBLAYES

TRANSVERSAL SECTION A-A'
COUPE TRANSVERSALE

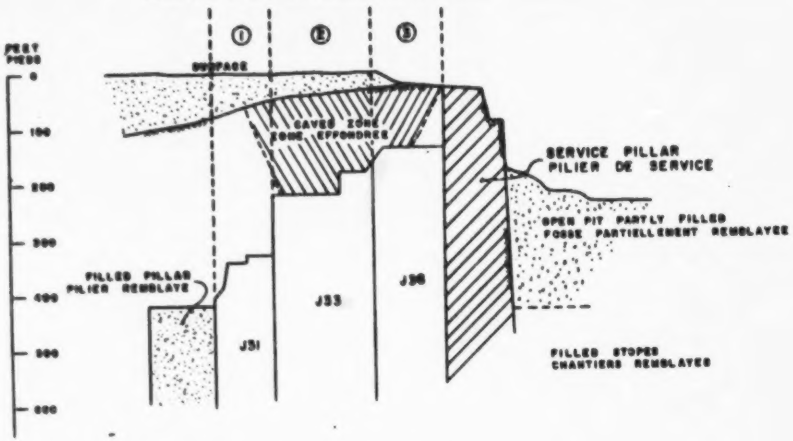
LEGEND - LEGENDE

V6 Andesite
Andésite

4P Peridotite
Péridotite


0
100
200
FEET - PIEDS

SURFACE PILLARS - PILIERS DE SURFACE


①
②
③
FEET
PIEDS
0
100
200
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500
600
SURFACE
CAVED ZONE
ZONE EFFONDREE
SERVICE PILLAR
PILIER DE SERVICE
OPEN PIT PARTLY FILLED
FOSSE PARTIELLEMENT REMBLAYEE
FILLED PILLAR
PILIER REMBLAYE
J31
J33
J36
FILLED STOPES
CHANTIERS REMBLAYES

LONGITUDINAL SECTION B-B'
COUPE LONGITUDINALE

ROCHE
associés ltée
Groupe conseil

[illegible]

MINE # 12 MINE

GEOMETRY OF PILLARS
GEOMETRIE DES PILIERS

Date 08/85
Figure 12.7

7) Blasting of the longitudinal pillar and the north half of the service pillar.

A retrospective analysis done by the Company, indicates that 35 000 tons were drawn from stope P-35 (or the equivalent of a height of 40 ft - 12 m) before the rock base caved-in. Even if fill from adjacent stopes has almost certainly seeped into P-35, theoretically a space of about 200 x 55 x 40 ft high (60 x 16.5 x 12 m) was created prior to the rupture of the surface pillar. Liquefied clay then seeped progressively through the crushed ore as far as level 460 or 450 ft (137 m) below the surface and the Company was forced to cease drawing from this stope because of excessive dilution. On the other hand, the lower part of this same pillar, from level 740 to level 460, was completely recovered - a sure sign that the clay became more cohesive as it became mixed with other materials.

In the sequence of events outlined above, the adoption of corrective measures is a very important step, effective in the short term; it also allowed the continuation of the recovery of ore from the upper area of the deposit. In fact, two independent firms examined the facts and concluded that the clay mixed with a high content of sand and gravel or with fill material from the concentrator; became less fluid, thus reducing infiltration.

Therefore, the Company immediatly filled in the caved-in area with classified tailings. Presently, a much larger surface than the caved-in area is covered with fill.

The last step (presently being carried out) has been to use the opening caused by the cave-in as a backfill raise.

The fill placed on the surface will combine with the clay and the whole mixture will weigh on the blasted ore. The longitudinal pillar, composed of pillars J-31, J-33 and J-36, will then be blasted and drawn in the sequence shown in Figure 12.8. In this way, they hope to be able to control the progression of the rupture of the andesite crown. If, however, it should cave-in, the fill will act as a cushion and will mix with the clay thus avoiding any risk of infiltration.

. Design Factors

As has just been seen, the Company's approach has been accented more on controling instability than on designing a stable surface pillar. Naturally, the initial cave-in had not been foreseen and serves as a reference for the design of a stable pillar. In this operation, the fill seems to have played an important limiting role, minimizing the extent of the rupture.

. Pillar Dimensions

For the purposes of this study, we separated the surface pillar into three transversal sections corresponding to the roofs of stopes J-31 and J-36 so as to indicate the progression of the thickness /width ratio. The dimensions obtained are compiled in Table 12.2 and illustrated in Figure 12.7.

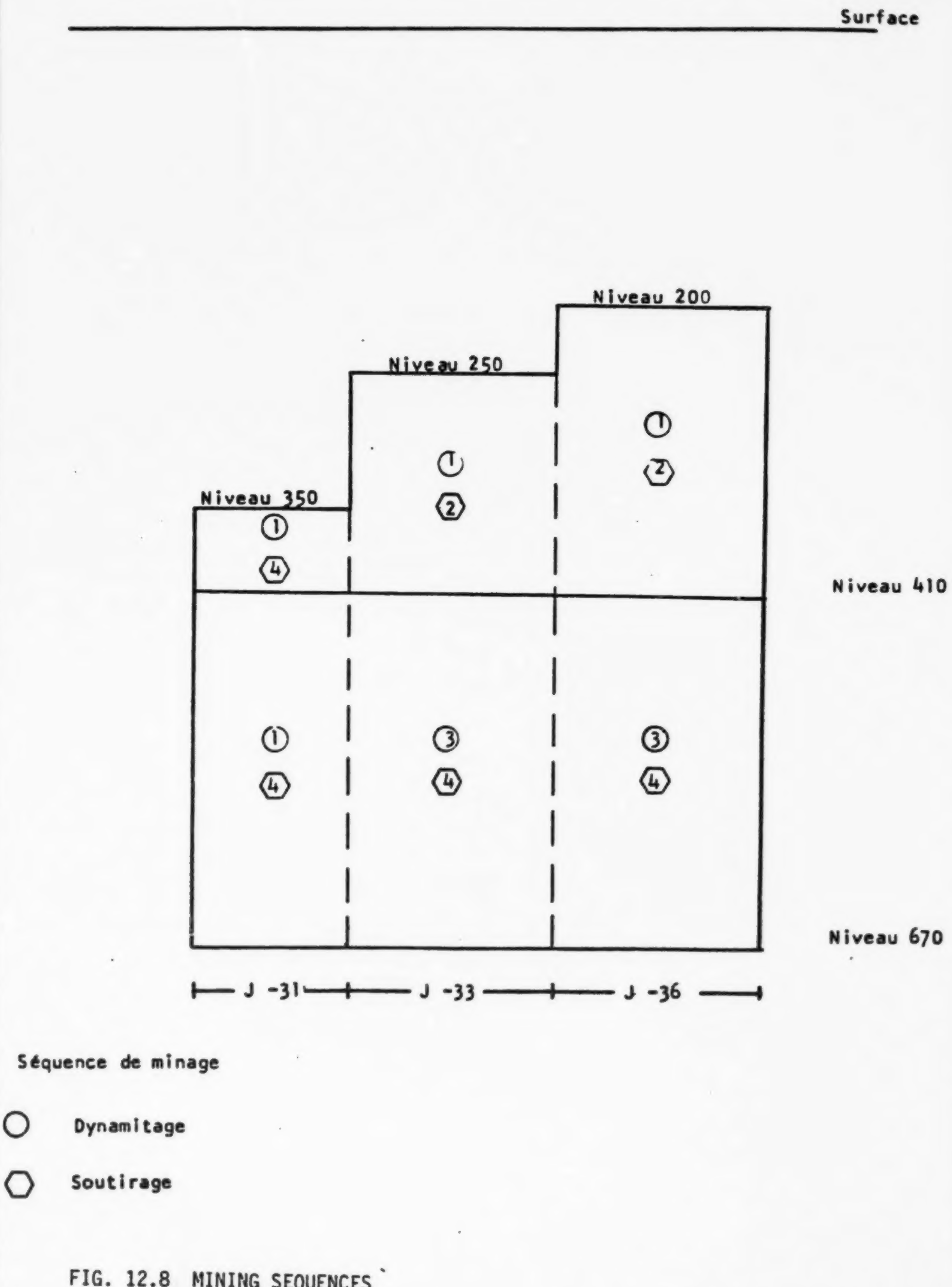
Surface
Niveau 200
Niveau 250
Niveau 350
Niveau 410
Niveau 670
① 4
① 2
① 2
① 4
③ 4
③ 4
J -31
J -33
J -36
Séquence de minage
○ Dynamitage
⬡ Soutirage

FIG. 12.8 MINING SEQUENCES
SEQUENCES DE MINAGE

DIMENSIONS OF SURFACE CROWN PILLARS

DIMENSIONS DES PILIERS DE SURFACE

TABLE 12,2
TABLEAU 12,2

DIMENSIONS		PILLARS - PILIERS							
		#1	#2	#3					
. THICKNESS: EPAISSEUR:									
- WATER BODY PLANS D'EAU	feet-pi. (m)	-	-	-					
- OVERBURDEN MORTS-TERRAINS	feet-pi. (m)	50 (15)	50 (15)	50 (15)					
. SURFACE CROWN PILLAR: PILIER DE SURFACE:									
- THICKNESS EPAISSEUR	feet-pi. (m)	110 (33,5)	180 (55)	260 (79)					
- WIDTH LARGEUR	feet-pi. (m)	300 (91)	300 (91)	300 (91)					
- LENGTH LONGUEUR	feet-pi. (m)	130 (40)	180 (55)	100 (30)					
- THICKNESS/WIDTH RATIO RAPPORT EPAISSEUR/LARGEUR		0,4	0,6	0,9					
. STOPE HEIGHT HAUTEUR DU CHANTIER	feet-pi. (m)	380 (116)	260 (79)	500 (152)					
. FILL HEIGHT HAUTEUR DU REMBLAI	feet-pi. (m)	380 (116)	260 (79)	500 (152)					

12.10 VISUAL EVALUATION OF THE SURFACE PILLAR(S)

There is no longer an access at the surface pillar level. However, we examined the hanging wall of the deposit parallel to the longitudinal pillar blasted to level 410. The influence of the relaxation of the mass is visible where it shows local oozing and separates into strata towards the stope. It is not possible to verify directly whether the fill takes up all the space created by the drawing of the block. It is obvious, however, that the fill reaches the level of the 450 drawing points. A model of silo flow could probably be applied in this case.

From an examination of the surface, it is possible to verify that the fill is seeping underground as intended. Numerous tension fissures show around the subsidence zone and the anchors previously used for surface displacement measurements are no longer operational. It is also impossible, without drilling, to determine whether there is further caving of the rock crown.

12.11 MANAGEMENT'S COMMENTS

In general, management feels that any research program on the safety and efficiency of mining methods would be essential to the Canadian mining industry. Fully aware that there are no miracle solutions and that each mine is different, they consider that the experience of other operations is important.

MINE #13

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13.0 SUMMARY OF THE VISIT

The mine is made up of massive and disseminated sulfides containing copper and some gold. The main ore zone is situated in a band of sericitized rock surrounded by anorthosite. The deposit has an average dip of 45° SE and strikes NE.

A large lake covers the surface pillars. About 10 ft (3 m) of soil covers the pillars; this soil is composed of sand, silt, clay and waste boulders that have been dumped on some of the pillars.

The rock mass is sericitized and oxidized in the area of the surface pillars. The oxidation level is of the gossan-type and various secondary copper minerals have developed. Water infiltration in the upper stopes is a equivalent to a mere dripping.

The stopes were worked with the cut-and-fill method and filled to within 8 ft (2.4 m) of the roofs.

The sizing of the surface pillars was based on geometric considerations.

No particular problem was mentionned in connection with the surface lake.

A well established visual inspection program and an alarm installed in one particular stope are proof of the Company's concern about the potential dangers from the lake and the oxidized zones in the rock mass.

13.1 GENERAL INFORMATION

. Regional Geology

The mining property is located in a belt of green rocks in the Superior Province, near the border of the Grenville Province. The rock is made up of mafic lava and felsic pyroclastics. The rock has folds running EW and is characterized by green schist facies. Numerous ultrabasic and granitic Archean intrusions cut across the formations.

. Local Geology

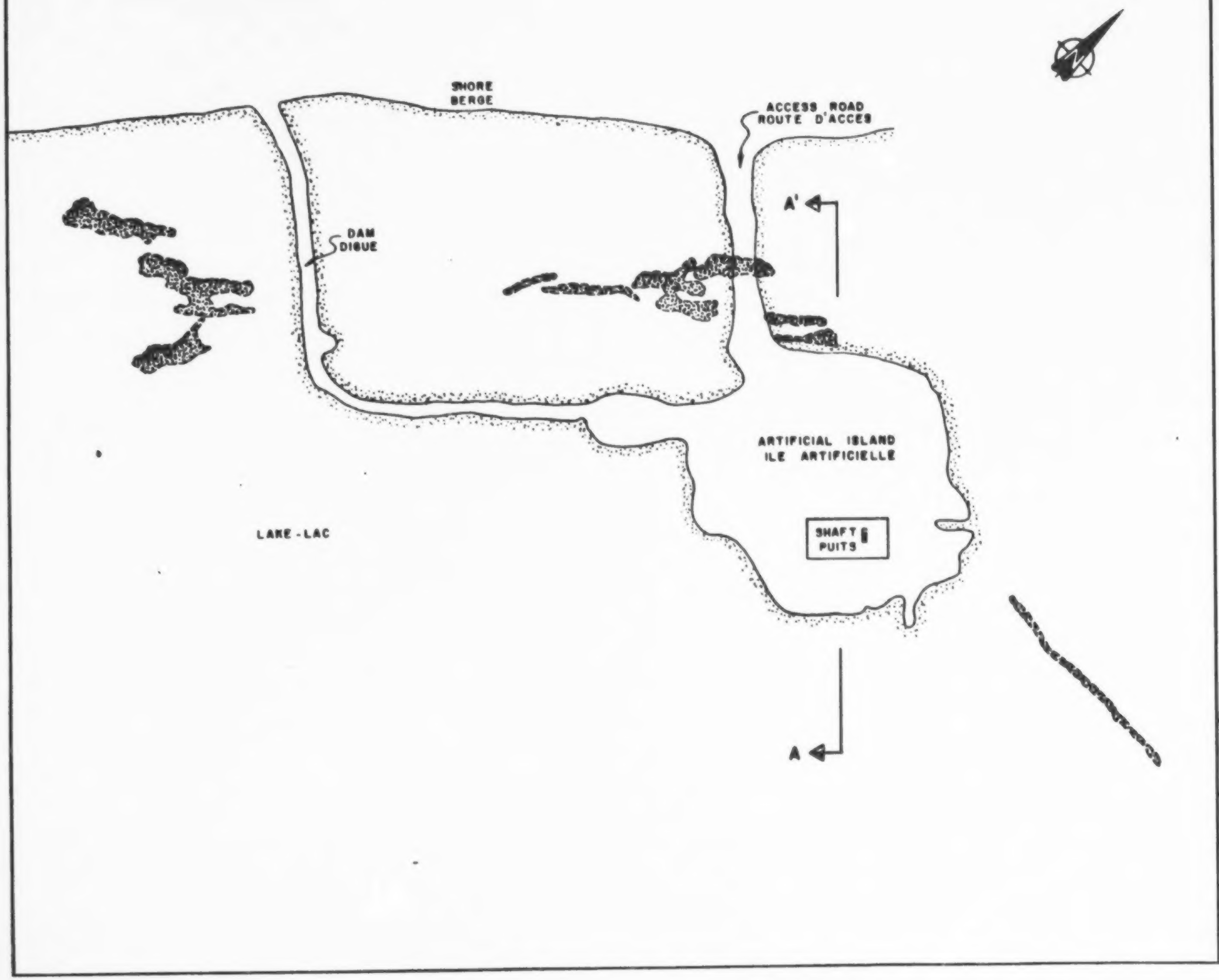
Typical of the mining ares is an anorthosite containing a zone that has been sheared and mineralized into copper and gold. (See figures 13.1 and 13.2).

Two anticlines striking NW are present in both an ultramafic intrusion located at the north end of the property and a granitic intrusion to the south. Two families of faults striking NE and NW cut across the anorthosite and granite.

. Characteristics of the Deposit

The deposit is located in a sericitized shearing zone striking NE, with a dip of about 45°SE, and in subsidence fractures striking approximatly EW in the anorthosite rock.

The shearing zone is made up of massive and disseminated sulfides containing chalcopyrite, pyrite,


SHORE
BERGE
ACCESS ROAD
ROUTE D'ACCES
A'
DAM
DIGUE
ARTIFICIAL ISLAND
ILE ARTIFICIELLE
SHAFT
PUITS
LAKE-LAC
A

LEGEND-LEGENDE

▨ Stope
Chantier

NOTE

1- Host-rock : anorthosite
Roche hôte : anorthosite

2- Partial view of stopes
Vue partielle des chantiers

0 100 200
FEET-PIEDS

ROCHE
associés ltée
Groupe conseil

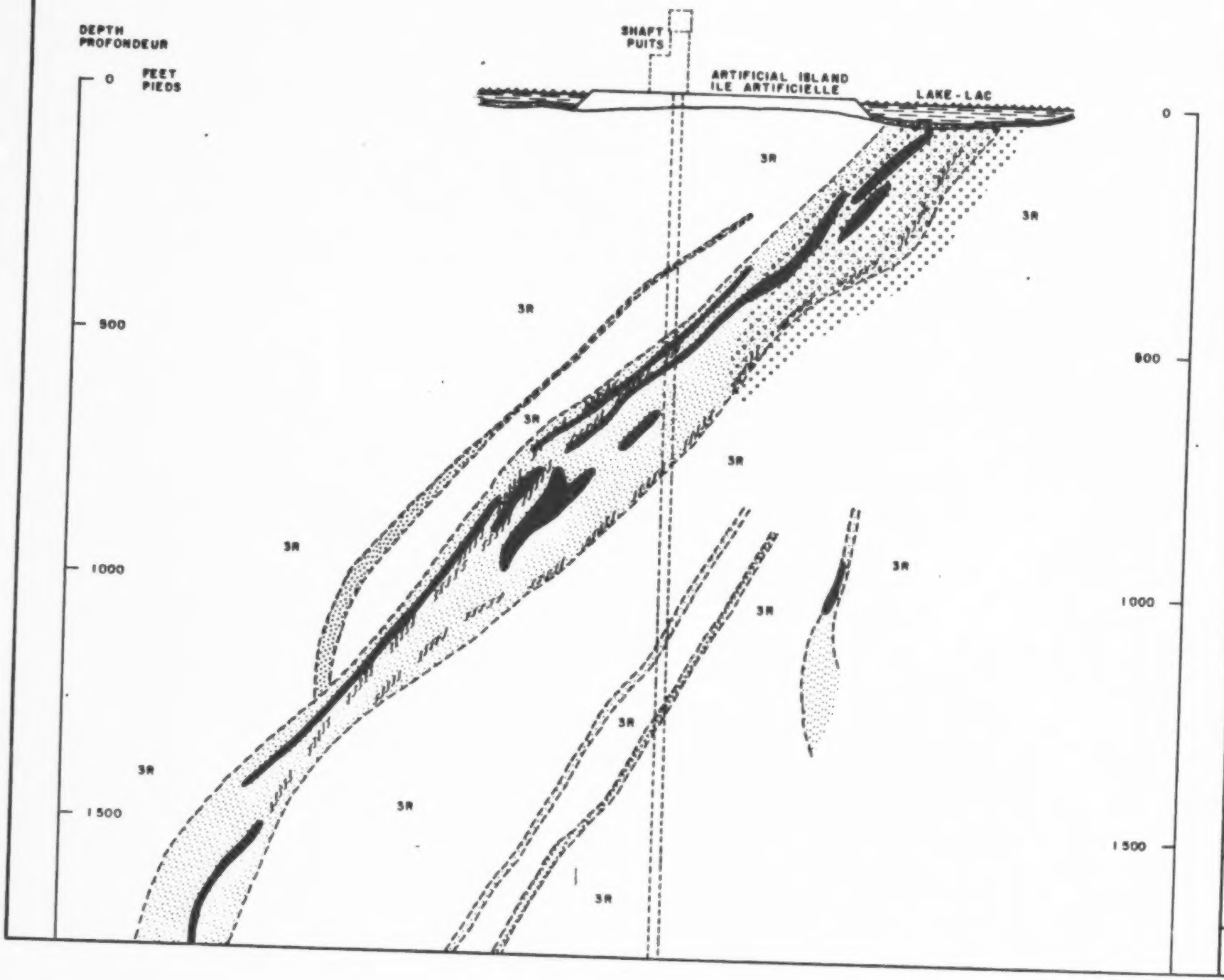
2535 boul Laurier
Sainte Foy, Québec
G1V 4M3 Canada
(418) 871 9880
Telex CB 051 31980

MINE # 13 MINE

SURFACE PLAN
PLAN DE SURFACE

Date 06/85

Figure 13.1


DEPTH
PROFONDEUR
FEET
PIEDS
0
500
1000
1 500
SHAFT
PUITS
ARTIFICIAL ISLAND
ILE ARTIFICIELLE
LAKE-LAC
3R
0
500
1000
1 500

LEGEND-LEGENDE

■	Ore zones Zones minéralisées
▨	Sericitized sheared zones Zones de schiste à séricite
▩	Mineralized quartz-calcite vein Veine minéralisée quartz-calcite
▦	Dyke
3R	Anorthosite
⁛	Oxidized zone Zone oxidée
⫽	Late stage faults Failles tardives

0 100 200
FEET-PIEDS

SECTION
· COUPE 'A-A'

ROCHE
associés ltée
Groupe conseil

2535 boul Laurier
Sainte-Foy Québec
G1V 4M3 Canada
(418) 871 [illegible]
Télex [illegible] 051 31[illegible]

MINE # 13 MINE

GEOLOGICAL SECTION
COUPE GEOLOGIQUE

Date	Figure
06/85	13.2

pyrhotite and gold and an oxidation zone containing secondary copper minerals. Veins of quartz and calcite mineralized into chalcopyrite, pyrite, gold and sphalerite in places fill the subsidence fractures.

The deposit is of tabular shape, composed of several veins located for the most part in the principal sericitized shearing zone. The dimensions of the deposit are:

Length	Width	Depth
2 000 ft	10-170 ft	2 000 ft
(610 m)	(3-52 m)	(610 m)

The deposit has a NE strike and 45°SE dip similar to the sericitized zone.

Production is continuous at nearly 800 t per day.

13.2 MINE ENVIRONMENT

The surface pillars are located beneath a lake of several square miles. The shaft is situated on an artificial lake linked to the shore by a road built on landfill. A dyke has been built between the island and the shore forming, with the access road, a basin which separates part of the surface pillars from the rest of the lake (Figure 13.1). The dyke would prove to be of considerable help in controling water infiltration in this part of the mine and could allow for the recovery of these pillars.

No sign of settlement has been observed on either the shore, the dyke or the artificial lake.

Two underground mines are located in the vicinity. The first is inactive and is located about 1 000 ft (305 m) south of the mine visited. The mines are connected by two drifts located at levels 275 and 525. Both these drifts are closed off by cement walls to prevent any possibility of flooding from the inactive mine.

The second mine is in operation and comes as close as 100 ft to the north-east side of the mine visited.

The stopes in the upper levels of the neighbouring mines have been filled and drained.

13.3 OVERBURDEN

. Studies

No geotechnical study has been undertaken on the soil covering the surface pillars. The average thickness of the soil is estimated at about 10 ft (3 m) as seen from a few vertical holes drilled from the frozen surface of the lake. The drill holes were later cemented up over at least 60 ft (18 m) from the collar. The drill holes pattern was 100 x 100 ft (30 x 30 m) and the length of the holes depended on the geological data that management hoped to obtain.

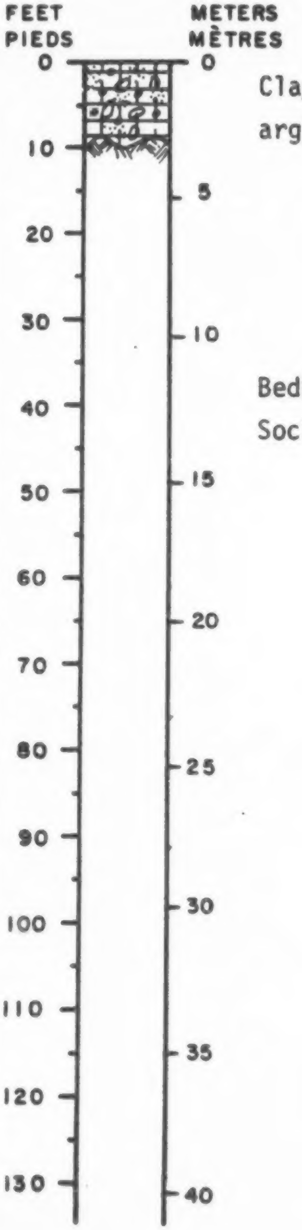
Presently, the entire length of the test holes drilled from the surface crossing part of the deposit has been cemented up.

According to the recommendations of an outside consultant, it would be imprudent to drill through this soil layer as it appears to act as an impermeable layer.

. Stratigraphy and Characteristics

The soil covering the surface pillars is composed of clay, silt, sand, gravel and boulders. Figure 13.3 is a stratigraphic cross-section in sketch form showing the soil over the pillars. Waste rock has been dumped in the basin mentioned in section 13.2. The layer of waste is evaluated at several feet thick. The topography of the rock is irregular.

SOIL STRATIGRAPHY
STRATIGRAPHIE DU SOL


FEET
PIEDS
METERS
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30
40
50
60
70
80
90
100
110
120
130
0
5
10
15
20
25
30
35
40

Clay, silt, sand, gravel and boulders 10 feet (3,0m)
argile, silt, sable, gravier et blocs 10 feet (3,0m)

Bedrock
Socle rocheux

Note: Lake at surface: depth 10-160 feet (3-48m)
Lac en surface: profondeur 10-160 pi (3-48m)

ROCHE associés ltée Groupe-conseil 2535, boul Laurier, Sainte-Foy, Québec G1V 4M3 Canada (418) 871 8800 Télex: QBC 051 31593	MINE # 13 MÎNE	Date 07-1985	Figure 13.3

13.4 ROCK MASS

. Nature of the Rock

The composition of the rock mass containing the ore is as follows:

Footwall : Anorthosite
Deposit : Sericitized zone
Hanging wall : Anorthosite

Two types of alterations characterize the rock mass:

1. Hydrothermal alteration as far as 2 500 ft (760 m) deep. (Sericitization zone).
2. Oxidation zones caused by water circulation going as deep as 1 000 ft (300 m). (Zones of secondary copper minerals).

. Structural Geology

Holes drilled above the surface pillars indicate that faults are common in the upper part of the deposit.

No statistical study of the joints has been conducted by management. However, they mention that water pressure in the joints is almost nil: the walls are damp, at most. Sericite, chlorite, quartz and calcite are the principal fill materials encountered in the joints. The interface between the deposit and the walls shows no separation. The interface is gradual: the schistosity disappears slowly into the walls as it moves from the sericitized zone.

. Characteristics

Table 13.1 shows some of the characteristics of the rock mass. These values are estimated on the basis of data gathered from a mine situated in the immediate vicinity.

TABLE 13.1

TABLEAU 13.1

ROCK CHARACTERISTICS

CARACTÉRISTIQUES DE LA ROCHE

VALEURS ESTIMÉES

LOCATION EMPLACEMENT		FOOT WALL ÉPONTE INFÉRIEURE	OREBODY GISEMENT	HANGING WALL ÉPONTE SUPÉRIEURE
ROCK TYPE TYPE DE ROCHE		Anorthosite	Sericitized zone Zone séricitisée	Anorthosite
DENSITY DENSITÉ		3.0	2.8 2.9	3.0
COMPRESSIVE STRENGTH RÉSISTANCE EN COMPRESSION	psi x 10^3 (MPa)	11.6 (80)	9.4 (65)	11.6 (80)
SHEAR STRENGTH RÉSISTANCE AU CISAILLEMENT	psi x 10^3 (MPa)	-	-	-
TENSILE STRENGTH RÉSISTANCE EN TENSION	psi x 10^3 (MPa)	-	-	-
POINT LOAD STRENGTH INDICE DE DOUBLE POINCONNEMENT	psi x 10^3 (MPa)	-	-	-
POISSON'S RATIO RAPPORT DE POISSON		-	-	-
YOUNG'S MODULUS MODULE DE YOUNG	psi x 10^6 (GPa)	-	-	-
RQD %		-	-	-
GEOMECHANICAL CLASSIFICATION CLASSIFICATION GÉOMÉCANIQUE	CSIR NGI	68 90	53 3	68 90

13.5 HYDROGEOLOGICAL CONDITIONS

. Overburden

The soil covering the surface pillars is under a layer of water averaging 60 ft (18 m) deep.

. Rock Mass

Four (4) pumping stations installed throughout the mine are used to pump about 2 000 (US)GPM (126 L/s) to the surface. Most of the infiltrated surface water is recuperated in a sump dug at level 1025. About 450 (US)GPM (28 L/s) are pumped from this level to the surface and the rest is transfered to the sump at level 1710.

13.6 MINING OPERATIONS

. Mining Methods

This mine uses the cut-and-fill method to recover the ore.

. Operating Conditions

The mining sequence in the stopes is from bottom to top, and in the mine in general, from top to bottom. No pillars are left in the stopes, thus the recovery rate is close to 100%. The stopes are mined in 8 ft (2.4 m) slices; drill holes are 6 ft (2 m) long and 1¼ in (3.2 cm) in diameter.

There is a period of about one month between the end of production in a stope and its filling. The upper stopes are filled to within 8 - 20 ft (2.4 - 6 m) of the roof; the average is, however, closer to 8 ft (2.4 m).

Management mentions that the effect of blasting on the stability of the underground structures is negligible.

13.7 SUPPORT AND REINFORCEMENT METHODS

. Primary Support

No wall pillars have been left in the upper stopes.

. Filling and Reinforcement

After complete recovery of the ore, each stope is systematically filled with hydraulic fill: the coarse mine tailings having a density of 2.93 and the following granulametric distribution:

# Mesh	% Passing
20	99.90
25	98.92
35	93.39
48	84.66
65	73.39
100	59.19
150	45.32
200	28.85
270	21.45
325	17.25

In places, the floors of certain stopes are made of fill and cement (ratio 20:1) but in general, no cement is added to the hydraulic fill. The drainage of the stopes is done by percolation with no wooden towers or drain pipes.

Conventional bolts 8 ft (2.4 m), and sometimes 5 ft (1.5 m) long are used in the rock walls. Normally, a

3 x 3 ft (0.9 x 0.9 m) bolting pattern is applied in the fractured zones forming blocks.

Wooden structures have been erected to consolidate the rockwalls around the ore schist in the upper levels in the drift following the strike of the deposit. In stopes wider than 30 ft (9 m), wooden scaffolding is installed between the fill and the roof to support part of the latter.

13.8 MONITORING PROGRAM(S)

. Stress Measurement

No stress measurements have been taken in the surface pillar area.

. Displacement Measurement

No displacement measurements have been carried out in the surface pillar area.

. Other Programs

Because of the presence of the lake on the surface, management developed and installed an alarm system on the roof of an upper stope. This system is composed of a network of electrical wiring connecting the anchor bolts fixed in the roof to a signal board located in the shaft control room. If a boulder or part of the roof falls or moves, one or several wires are cut and the alarm system is automatically set off.

A visual inspection program for the upper stopes is well established; an inspection is carried out every two weeks and an inspection form filled out for each visit. Changes observed in the roof, walls, fill, steel, wood and bolts are noted on this form as well as the work being done.

13.9 SURFACE PILLAR DESIGN

. Personnel Involved

The persons and departments involved in pillar design are shown in Figure 13.4. At the beginning of the exploitation of the upper stopes in 1964, the Mine Manager was responsable for the sizing of the surface pillars. The Inspector of Mines (Provincial Government) acted as technical and legal advisor to the Superintendent.

. Chronology

The upper stopes were worked between 1964 and 1967. Since this time, no major change has been made in the stopes.

. Design Factors

After analysing local conditions and in order to maintain the long term stability of the surface pillars, management requested the opinion of an outside consultant.

The evaluation done by this consultant indicates that stability conditions have been respected and that no drilling should be carried out through the layer of soil covering the pillars in order to preserve the

ORGANIZATION CHART - PILLARS DESIGN
ORGANIGRAMME - CONCEPTION DES PILIERS

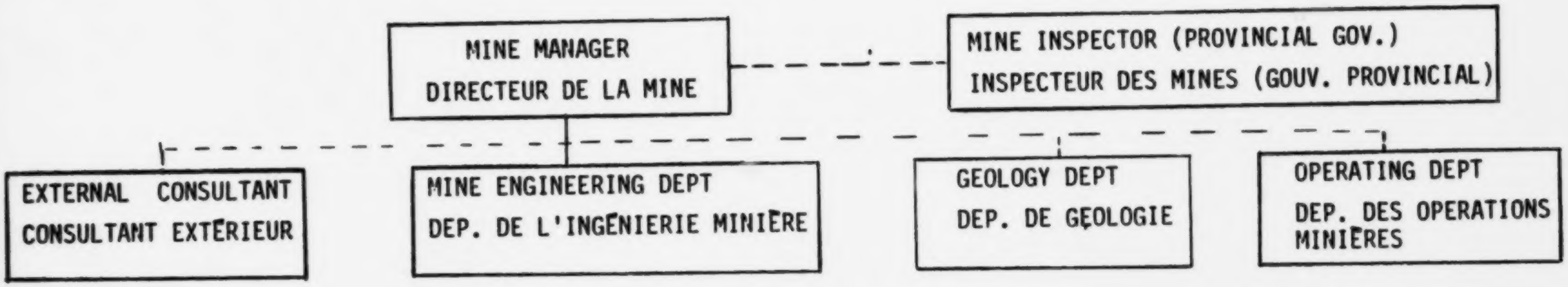
MINE MANAGER
DIRECTEUR DE LA MINE
MINE INSPECTOR (PROVINCIAL GOV.)
INSPECTEUR DES MINES (GOUV. PROVINCIAL)
EXTERNAL CONSULTANT
CONSULTANT EXTÉRIEUR
MINE ENGINEERING DEPT
DEP. DE L'INGÉNIERIE MINIÈRE
GEOLOGY DEPT
DEP. DE GÉOLOGIE
OPERATING DEPT
DEP. DES OPERATIONS MINIÈRES

Figure 13.4

impermeability of the rock mass. The minimum thickness of the surface pillars had been fixed beforehand by management at 80 ft (24 m) or 2.5 times the width of the stopes for stopes wider than 32 ft (10 m). According to the consultant mentioned previously, the minimum thickness of the pillars showing signs of advanced oxidation should be increased to 120 ft (37 m) and the maximum width tolerated in the underlying stopes should be 25 ft (8 m).

. Pillar Dimensions

Table 13.2 gives the dimensions of the surface pillars across this mine. The average thickness/width ratio is 7.7 with extremes ranging from 0.9 to 32.

DIMENSIONS OF SURFACE CROWN PILLARS

DIMENSIONS DES PILIERS DE SURFACE

TABLE 13,2
TABLEAU 13,2

DIMENSIONS		PILLARS - PILIERS							
		#1	#2	#3	#4	#5	#6	#7	#8
. THICKNESS: EPAISSEUR:									
- WATER BODY PLANS D'EAU	feet-pi. (m)	10 (3)	10 (3)	16 (5)	25 (8)	25 (8)	16 (5)	16 (5)	35 (11)
- OVERBURDEN MORTS-TERRAINS	feet-pi. (m)	10 (3)	10 (3)	10 (3)	10 (3)	10 (3)	10 (3)	10 (3)	10 (3)
. SURFACE CROWN PILLAR: PILIER DE SURFACE:									
- THICKNESS EPAISSEUR	feet-pi. (m)	75 (23)	75 (23)	80 (24)	160 (49)	120 (37)	80 (24)	100 (30)	90 (27)
- WIDTH LARGEUR	feet-pi. (m)	20 (6)	35 (11)	20 (6)	5 (1,5)	15 (5)	30 (9)	10 (3)	40 (12)
- LENGTH LONGUEUR	feet-pi. (m)	310 (94)	50 (15)	175 (55)	70 (27)	140 (43)	185 (56)	77 (24)	50 (15)
- THICKNESS/WIDTH RATIO RAPPORT EPAISSEUR/LARGEUR		3,8	2,1	4,0	32,0	8,0	2,7	10,0	2,3
. STOPE HEIGHT HAUTEUR DU CHANTIER	feet-pi. (m)								
. FILL HEIGHT HAUTEUR DU REMBLAI (approx)	feet-pi. (m)	145 (44)	170 (52)	185 (56)	60 (78)	20 (6)	150 (46)	100 (30)	75 (23)

DIMENSIONS OF SURFACE CROWN PILLARS

DIMENSIONS DES PILIERS DE SURFACE

TABLE 13,2
TABLEAU 13,2

DIMENSIONS		PILLARS - PILIERS							
		#9	#10	#11	#12	#13	#14	#15	#16
. THICKNESS: EPAISSEUR:									
- WATER BODY PLANS D'EAU	feet-pi. (m)	20 (6)	45 (14)	10 (3)	16 (5)	87 (27)	110 (33)	90 (27)	160 (49)
- OVERBURDEN MORTS-TERRAINS	feet-pi. (m)	10 (3)	10 (3)	10 (3)	10 (3)	10 (3)	10 (3)	10 (3)	10 (3)
. SURFACE CROWN PILLAR: PILIER DE SURFACE:									
- THICKNESS EPAISSEUR	feet-pi. (m)	70 (21)	150 (46)	100 (30)	70 (21)	175 (53)	75 (23)	175 (53)	100 (30)
- WIDTH LARGEUR	feet-pi. (m)	20 (6)	10 (3)	15 (5)	25 (8)	15 (5)	20 (6)	10 (3)	10 (3)
- LENGTH LONGUEUR	feet-pi. (m)	60 (18)	80 (21)	90 (27)	260 (77)	330 (101)	350 (107)	330 (101)	215 (67)
- THICKNESS/WIDTH RATIO RAPPORT EPAISSEUR/LARGEUR		3,5	15,0	6,7	2,8	11,7	3,8	17,5	10,0
. STOPE HEIGHT HAUTEUR DU CHANTIER	feet-pi. (m)								
. FILL HEIGHT HAUTEUR DU REMBLAI (approx)	feet-pi. (m)	150 (46)	45 (14)	130 (40)	100 (61)	40 (12)	130 (40)	40 (12)	50 (15)

DIMENSIONS OF SURFACE CROWN PILLARS

DIMENSIONS DES PILIERS DE SURFACE

TABLE 13,2
TABLEAU 13,2

DIMENSIONS		PILLARS - PILIERS							
		#17	#18	#19	#20	#21	#22	#23	#24
. THICKNESS: EPAISSEUR:									
- WATER BODY PLANS D'EAU	feet-pi. (m)	150 (46)	110 (33)	110 (33)	95 (29)	100 (30)	90 (22)	100 (30)	65 (20)
- OVERBURDEN MORTS-TERRAINS	feet-pi. (m)	10 (3)	10 (3)	10 (3)	10 (3)	10 (3)	10 (3)	10 (3)	10 (3)
. SURFACE CROWN PILLAR: PILIER DE SURFACE:									
- THICKNESS EPAISSEUR	feet-pi. (m)	170 (52)	90 (27)	80 (24)	80 (24)	90 (27)	90 (27)	90 (27)	100 (30)
- WIDTH LARGEUR	feet-pi. (m)	10 (3)	15 (5)	20 (6)	30 (9)	35 (11,7)	20 (6)	50 (15)	12 (4)
- LENGTH LONGUEUR	feet-pi. (m)	160 (49)	205 (64)	120 (37)	150 (46)	235 (71)	50 (15)	250 (70)	270 (82)
- THICKNESS/WIDTH RATIO RAPPORT EPAISSEUR/LARGEUR		17,0	6,0	4,0	2,7	2,6	4,5	1,8	8,3
. STOPE HEIGHT HAUTEUR DU CHANTIER	feet-pi. (m)								
. FILL HEIGHT HAUTEUR DU REMBLAI (Approx.)	feet-pi. (m)	100 (30)	70 (21)	40 (12)	115 (35)	40 (12)	50 (15)	60 (18)	45 (14)

DIMENSIONS OF SURFACE CROWN PILLARS

DIMENSIONS DES PILIERS DE SURFACE

TABLE 13,2
TABLEAU 13,2

DIMENSIONS		PILLARS - PILIERS							
		#25	#26	#27	#28	#29	#30	#31	#32
. THICKNESS: EPAISSEUR:									
- WATER BODY PLANS D'EAU	feet-pi. (m)	35 (11)	10 (3)	80 (24)	55 (17)	40 (12)	40 (12)	40 (12)	10 (3)
- OVERBURDEN MORTS-TERRAINS	feet-pi. (m)	10 (3)	10 (3)	10 (3)	10 (3)	10 (3)	10 (3)	10 (3)	10 (3)
. SURFACE CROWN PILLAR: PILIER DE SURFACE:									
- THICKNESS EPAISSEUR	feet-pi. (m)	100 (30)	210 (64)	115 (35)	100 (30)	90 (27)	80 (24)	110 (33)	100 (30)
- WIDTH LARGEUR	feet-pi. (m)	40 (12)	10 (3)	10 (3)	15 (5)	100 (30)	30 (9)	15 (5)	10 (3)
- LENGTH LONGUEUR	feet-pi. (m)	180 (55)	40 (12)	120 (37)	200 (61)	180 (55)	180 (55)	130 (40)	470 (143)
- THICKNESS/WIDTH RATIO RAPPORT EPAISSEUR/LARGEUR		2,5	21,0	11,5	6,7	0,90	2,7	7,3	10,0
. STOPE HEIGHT HAUTEUR DU CHANTIER	feet-pi. (m)								
. FILL HEIGHT HAUTEUR DU REMBLAI (Approx)	feet-pi. (m)	180 (55)	10 (3)	10 (3)	60 (18)	80 (24)	90 (27)	60 (18)	90 (27)

13.10 VISUAL EVALUATION OF THE SURFACE PILLAR(S)

Eleven (11) upper stopes and numerous drifts were evaluated during this visit.

In general, local dripping has been observed on the walls and ceilings of the stopes. The bolting pattern in most of the stopes is 3 x 3 ft (0.9 x 0.9 m). A slight stream of water flows from some drill holes.

The walls are generally altered: gossan-type oxidized zones are often visible on the rock walls. Calcite, copper oxides and quartz (chert) are the main secondary minerals observed in the oxidized and shearing zones.

The primary structures of the walls are either practically non-existent or altered (gossan type). However, schistosity is well developed in certain stopes.

Among the eleven (11) stopes, four (4) had almost dry walls: in the first, bolts were used only locally; in the second, quartz ore breccia several feet wide was observed; in the third, semi-detached boulders hung from the ceiling, and in the fourth stope, the rock walls were massive without obvious alteration.

The stope containing the network of wiring to the bolts had some dripping in places. The bolting pattern was 3 x 3 ft (0.9 x 0.9 m).

Wooden scaffolding located between the fill and the roof was seen in only one stope. The roof of this stope had not been systematically bolted.

The R.Q.D. value varies widely from one stope to another (0 - 70) and even inside a single stope except in one stope where it is estimated at 70-80.

The stope have been filled to within about 8 ft (2.4 m) of the roof, except in certain stopes where the fill is within about 20 ft (6 m).

13.11 MANAGEMENT'S COMMENTS

Management mentions that in the lower stopes, the roof is becoming generally unstable and could even cave in if the thickness/width ratio of the crown pillars is less than 1.5.

Given the oxidized surface pillars, it is important to carry out an inspection regularly (twice a month) on the underlying stopes. When these stopes are inaccessible, a drift must be opened for this inspection. The latter must be done only by experienced personnel and, if possible, by the same persons from one inspection to the next.

Management mentions that the design of the surface pillars located beneath a lake begins with a conservative approach, i.e. leaving a considerable thickness of pillar and later mining gradually upwards along those stopes presenting stable ground conditions.

MINE #14

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14.0 SUMMARY OF THE VISIT

The property is composed of a group of five (5) ore zones; zone no. 3, the main one, will be the subject of the present study. The rock formations of this zone are sub-vertical and characterized by a high degree of schistosity and a variable percentage of sericite, concentrated along the planes of this schistosity. The ore zone is of tabular form, strikes EW and dips 85°S.

The zone is worked over a length of about 1 640 ft (500 m) for a width of about 50 ft (15 m) on average. The surface pillar covers only the stope situated at the eastern extremity of the property; the other stopes have been exploited right to the surface. In this sector, the overburden has been stripped to the rock, but the surface pillar is still covered with 10 to 20 ft (3 to 6 m) of silty clay and till.

As there is no major aquifer on the site, water comes mainly from precipitation and melting snow.

The Company uses a mining method similar to block caving by sub-levels and uses as fill, waste from an open pit operation. The fill is deposited on the surface over the stopes and fed down into the mine by gravity. The stope situated beneath the surface pillar is filled by a raise running through its center.

Lastly, the sizing of the surface pillar is based on economic and geometric criteria.

14.1 GENERAL INFORMATION

. Regional Geology

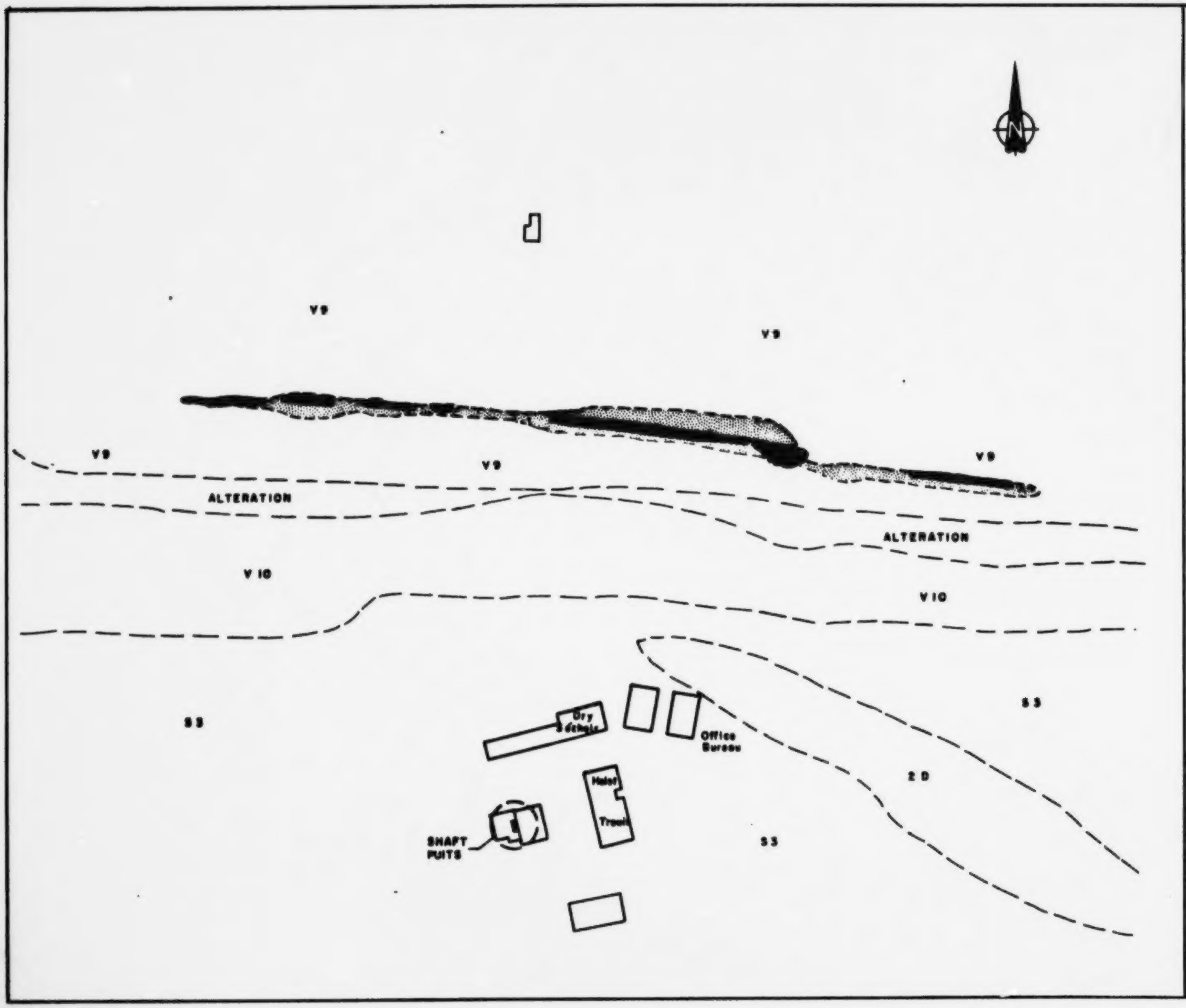
The property, in an Archean complex in the southern part of the Superior Province, is situated in a major volcanic belt striking east to west. The southern part of this zone is bordered by a major fault visible for several hundred kilometers. The ore horizon is part of a homoclinal sequence made up of a group of sedimentary rocks mainly composed of graywacke in the south and a second horizon of sedimentary rocks followed by felsic and mafic volcanic rocks in the north. The regional metamorphic facies is made up of green schist.

. Local Geology

On the property, the group containing the ore horizons is an assemblage of volcanic rock of varied composition, of pyroclastics and tuff. All these formations are sub-vertical with a dip of about 85°S and an EW strike as illustrated in figures 14.1 and 14.2.

. Characteristics of the Deposit

The horizons of pyrites mineralized into gold are of the volcanic type, and may be divided into five (5) principal zones; the largest, zone #3, reaches the soil-rock interface. Zones #4 and #5 are worked by an open pit mine, while zones #1 and #2 are discontinuous. Zone #3 is of tabular shape and of variable thickness;


N
V9
V9
V9
V9
V9
ALTERATION
ALTERATION
V 10
V 10
S3
S3
S3
2 D
Dry
Séchoir
Office
Bureau
Hoist
Treuil
SHAFT
PUITS

LEGEND - LEGENDE

▨ Ore zone
Zone minéralisée

■ Stope
Chantier

2D Diorite
Diorite

S3 Sediment, graywacke
Sédiments, grauwacke

V9 Mafic tuff
Tuf mafique

V10 Pyroclastic, tuff, agglomerat
Pyroclastique, tuf, agglomérats

0 10 20 m

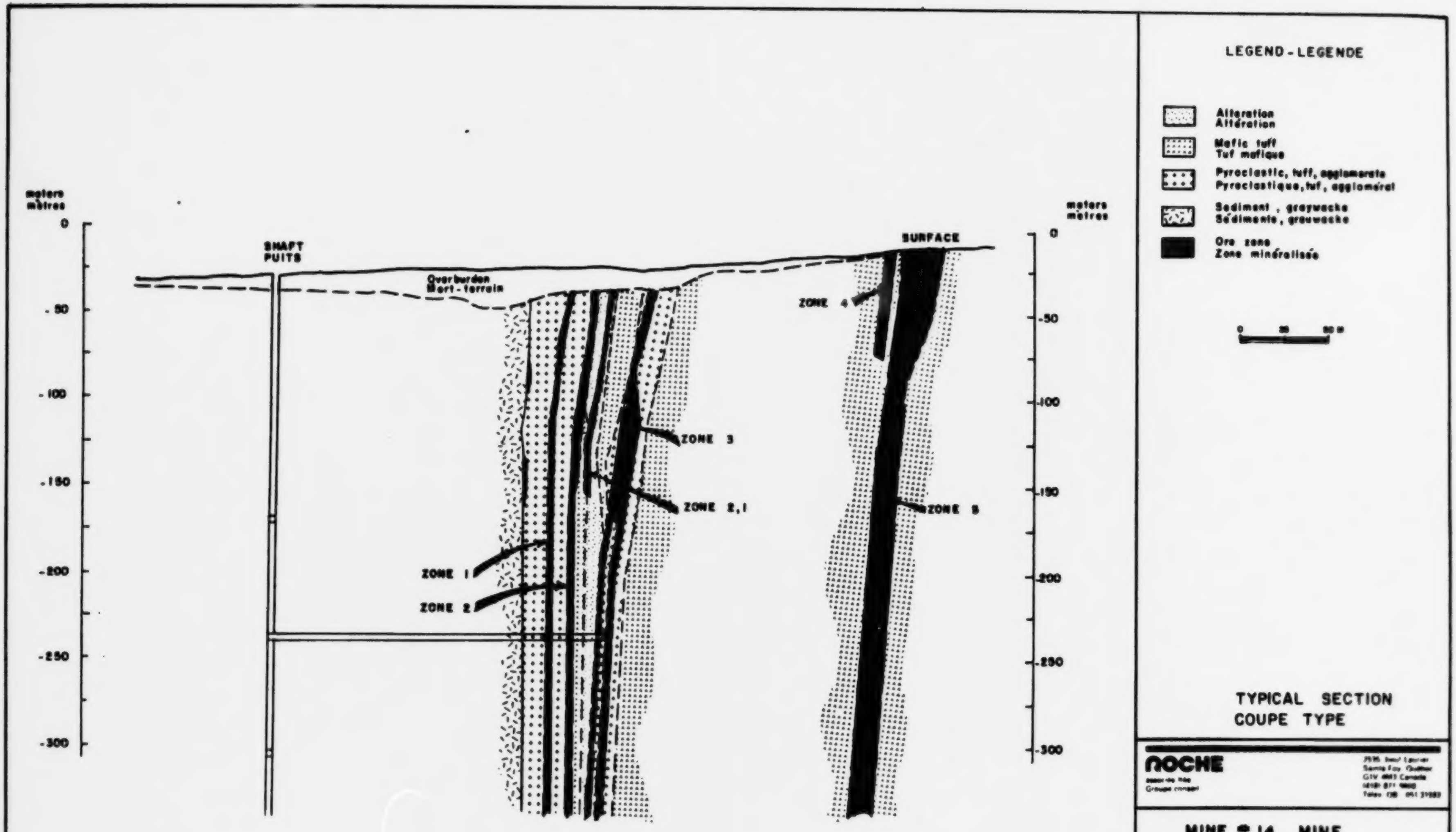
ROCHE
associés ltée
Groupe conseil

[illegible]

MINE # 14 MINE

SURFACE PLAN
PLAN DE SURFACE

Date	Figure
07 - 1985	14.1


LEGEND - LEGENDE
Alteration
Altération
Mafic tuff
Tuf mafique
Pyroclastic, tuff, agglomerate
Pyroclastique, tuf, agglomérat
Sediment, greywacke
Sédiments, grauwacke
Ore zone
Zone minéralisée
0
25
50 m
metres
mètres
0
-50
-100
-150
-200
-250
-300
SHAFT
PUITS
Overburden
Mort-terrain
SURFACE
ZONE 1
ZONE 2
ZONE 3
ZONE 2,1
ZONE 4
ZONE 5

TYPICAL SECTION
COUPE TYPE

ROCHE
[illegible]
Groupe conseil

[illegible] Laurier
Sainte-Foy Québec
G1V [illegible] Canada
[illegible]
Telex [illegible]

MINE # 14 MINE

GEOLOGICAL SECTION
COUPE GEOLOGIQUE

Date	Figure
07/85	14.2

the gold-bearing pyrite is either disseminated or in vein form. Its dip, like that of the surrounding formations, is 85°.

The dimensions of this zone (to be discussed in the study) are as follows:

Length	Width	Depth
1 640 (500 m)	10-115 ft (3-35 m)	Undetermined

The mine has been in continuous production since 1979 at a daily rate of about 1 400 tons.

14.2 MINE ENVIRONMENT

The topography of the site is relatively flat. No surface installation is situated directly over or in the immediate vicinity of zone #3, as shown in Figure 14.2.

A sedimentation basin and the surface infrastructures of this operation are located in the grauwacke formation 420 to 1 000 ft south of the ore zone.

The surface pillar under study is located in the extreme eastern part of the ore zone, though elsewhere the ore has been mined right to the surface leaving only a few rib pillars. The effect of these pillars on the stability of the walls will be considered and discussed further along in this study.

Aside from the recovery of zone #3, no other significant opening affects the surface pillar. There is no mine, lake or swamp in this area.

14.3 OVERBURDEN

. Studies

At the start, the property was covered by 10 to 20 ft (3 to 6 m) of overburden, as demonstrated by a geotechnical study conducted over zone #3. Vertical holes 7½ in (diameter) (19 cm) were drilled through the overburden to the rock interface along two lines parallel to the main axis of this zone. The test lines were 115 ft (35 m) apart with the longitudianl axis of the ore half way between; 130 ft (40 m) spaces were left between the holes themselves on each of the base lines. Diamond drilling conducted during the exploration of the deposit in this sector was also used to determine the rock profile.

. Stratigraphy and Characteristics

The stratigraphy of the soil shown in Figure 14.3 indicates that it is mainly composed of a mixture of gravel and till at the base, covered by silty clay. The data is as follows:

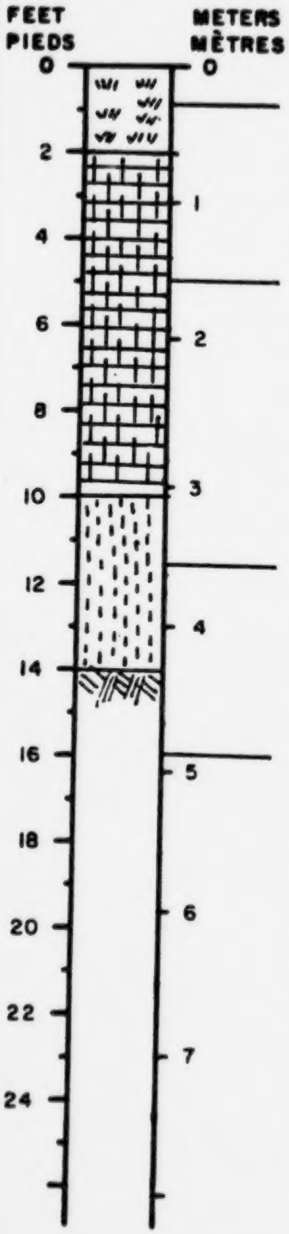
Silty Clay

. Percentage of water	35%
. Liquidity limit	45%
. Plastic limit	22%
. Plastic index	21-23%

Glacial Till

. Percentage of water	8-10%

SOIL STRATIGRAPHY
STRATIGRAPHIE DU SOL


FEET
PIEDS
METERS
MÈTRES
0
2
4
6
8
10
12
14
16
18
20
22
24
0
1
2
3
4
5
6
7

Peat moss, organic soil	1.5 - 2 feet	(0,4 -0,6m)
Tourbe, sol organique	1.5 - 2 pi	(0,4 -0,6m)
Silty clay	5 - 8 pi	(1,5 - 2,4m)
Argile silteuse	5 - 8 pi	(1,5 - 2,4m)
Glacial till, gravel	3 - 4 feet	(0,9 - 1,2m)
Till glaciaire, gravier	3 - 4 pi	(0,9 - 1,2m)
Bedrock		
Socle rocheux		

Note: above the east part of no 3 ore zone
au-dessus de la zone minéralisée no 3

ROCHE
associés ltée
Groupe-conseil

2535, boul Laurier,
Sainte-Foy, Québec
G1V 4M3 Canada
(418) 871 9800
Télex : QBC 051 31593

MINE # 14 MINE

Date 07-1985

Figure 14.3

14.4 ROCK MASS

. Nature of the Rock

The footwall immediately inside the principal zone (zone #3) is generally composed of mafic to sericitic tuff. The economic zone is of intermediate tuff forming a transition between the walls. The corresponding hanging wall, on the other hand, is formed of pyroclastic acid rock which is also sericitic.

The rock in this sector is very schistic and shows a concentration of sericite along the schistosity planes. Locally, mud fractures from the alteration of the sericite are due to a combined effect of the water and the crushing.

. Structural Geology

As has been pointed out, the tuff is finely ribboned and appears schistic. The width of these bands ranges from 1/8 in (3 mm) to several inches or centimeters.

No major faults cross the ore zone. The high degree of schistosity in the rock of the ore zone and the immediate walls is responsible for the incompetence of the rock mass. Finally, aside from this marked schistosity striking EW and steeply dipping to the south (80-85°), two family of joints are present. The first one runs parallel to the schistosity and dip flatly to the north (20-45°). Finally, steeply dipping structures normal to the schistosity are also present.

. Characteristics

The geomechanical characteristics of the rock available at the time of the visit are compiled in Table 14.1. The minimal values of the uniaxial compressive strength are obtained from point load testing. On the other hand, the highest values correspond to tests carried out perpendicular to the schistosity. No compressive test has been done in the laboratory because of the difficulty of acquiring cores sufficiently intact to be representative of the condition of the rock mass.

This becomes obvious from looking at the R.Q.D. values obtained for rocks from the deposit and from the walls. These values range from 0 to 70% and may be strongly influenced by the angle of the test holes in relation to the schistosity. According to mine personnel, it seems that the interface between the footwall and the ore zone is clean and solid, with little alteration material; the hanging wall is determined by the cutoff grade of the ore.

ROCK CHARACTERISTICS

CARACTÉRISTIQUES DE LA ROCHE

TABLE 14.1

TABLEAU 14.1

LOCATION EMPLACEMENT		FOOT WALL ÉPONTE INFÉRIEURE	OREBODY GISEMENT	HANGING WALL ÉPONTE SUPÉRIEURE
ROCK TYPE TYPE DE ROCHE		Maffic Tuff Tuf mafique	Intermediate Tuff Tuf intermédiaire	Pyroclastic Rocks Roches pyroclastiques
DENSITY DENSITÉ		2.77	3.04	2.77
COMPRESSIVE STRENGTH RÉSISTANCE EN COMPRESSION	psi x 10^3 (MPa)	3-8.6 (21-59)	1.9-9 (13-62)	1-1.5 (7-10)
SHEAR STRENGTH RÉSISTANCE AU CISAILLEMENT	psi x 10^3 (MPa)	-	-	-
TENSILE STRENGTH RÉSISTANCE EN TENSION	psi x 10^3 (MPa)	-	-	-
POINT LOAD STRENGTH INDICE DE DOUBLE POINCONNEMENT	psi x 10^3 (MPa)	-	-	-
POISSON'S RATIO RAPPORT DE POISSON		-	-	-
YOUNG'S MODULUS MODULE DE YOUNG	psi x 10^6 (GPa)	-	-	-
RQD %		50-70	0-20	0
GEOMECHANICAL CLASSIFICATION CLASSIFICATION GÉOMÉCANIQUE				

14.5 HYDROGEOLOGICAL CONDITIONS

. Overburden

At the soil level, it has been shown that there is no substantial aquifer in the immediate area of the exploited zone. There is not enough water to liquefy the silty clay and create a potential danger for underground operations.

In the western sector of zone #3, the ground has been stripped over the whole deposit. At the edges of the stripping, there were dips of overburden of about 40-45° and a drainge ditch has been dug around the mining zones to channel stream water.

Generally, the soil is dry except during strong precipitation and when the snow melts.

. Rock Mass

Very little information is available about the flow of water in the rock. It is, however, obvious that the action of the water on the sericite contained in the schistosity planes considerably decreases the strength of the rock.

Finally, the pumping rate ranges from 170 to 200 (I) GPM (13 to 15 L/s) and is proportionnal to the precipitation rate.

14.6 MINING OPERATIONS

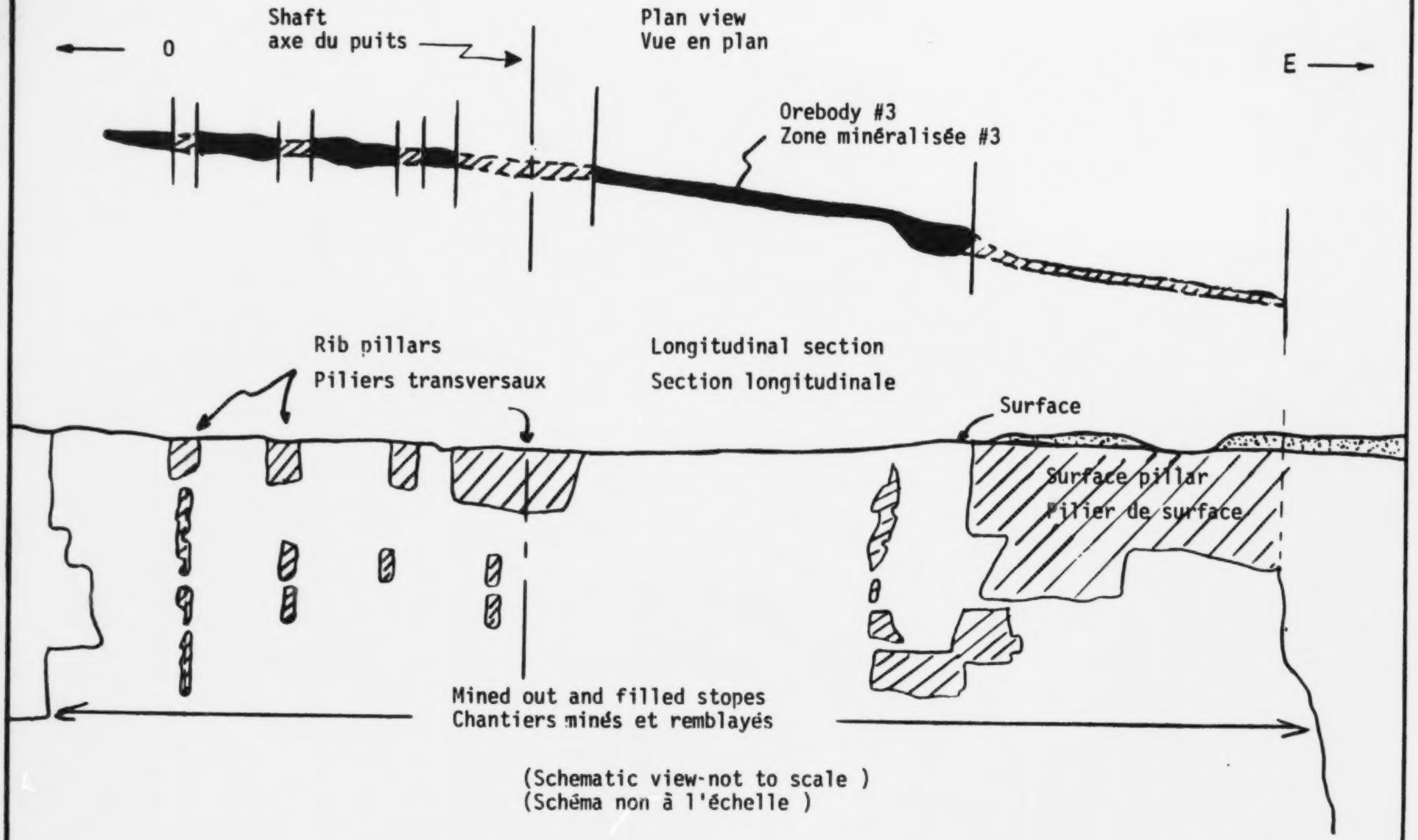
. Mining Methods

The mining method used is a modified version of block caving by sub-levels with unconsolidated rock fill. The sub-levels are spaced at intervals of 30 to 50 ft (9 to 15 m) and mining progresses along the longitudinal axis of the ore zone. In deeper sectors where the width exceeds 50 ft (15 m) , the deposit is mined transversally. The average width of zone #3, near the surface, is 15 ft (4.6 m).

. Operating Conditions

Close to 100% ore recuperation is possible with this method. A general view of the position of the different kinds of pillars existing in this mine is illustrated in Figure 14.4. Thus, if we keep to the strict definition of surface pillars, only the eastern part of the deposit has such a pillar. The central and western sectors of the vein have been mined to the surface except for the rib pillars.

At the upper levels of the mine, dilution is estimated at about 15%, but may be as much as 25% elsewhere. Mining is carried out from the top towards the bottom, after the stripping of the overburden at the western and central part of zone #3. Stopes are drilled upwards from each sub-level with holes 3½ in (89 mm) in diameter and about 40 ft (12 m) long. The drill hole pattern consists of a series of holes laid in out a fan-shape with 5 ft (1.5 m) spacing and a burden of five ft (1.5 m).


0
Shaft
axe du puits
Plan view
Vue en plan
E
Orebody #3
Zone minéralisée #3
Rib pillars
Piliers transversaux
Longitudinal section
Section longitudinale
Surface
Surface pillar
Pilier de surface
Mined out and filled stopes
Chantiers minés et remblayés

(Schematic view-not to scale)
(Schéma non à l'échelle)

Figure 14.4

Because of the poor quality of the ground, the drill holes must be lined with a rigid plastic pipe in order to maintain the necessary space for the introduction of the explosives. As it is, in several places, particularly if drilling is done a long time before the blasting, the walls of the holes tend to move creating an obstruction in the cavity.

At this mine, the fill is dumped at the surface of the deposit and thus flows into the stopes immediately following the recovery of the dynamited ore.

Finally, the mine is worked by retreating from the axis of the shaft toward the extremities of the ore zone.

14.7 SUPPORT AND REINFORCEMENT METHODS

. Primary Support

Near the surface, rib pillars about 32 ft (10 m) thick and spaced at intervals of about 100 ft (30 m) in the western sector, insure the general stability of the walls. A more sizeable pillar was left in the axis of the shaft while the central area of the ore zone is open over more than 460 ft (140 m) in length.

. Filling and Reinforcement

The filling of the stopes from the surface is possible given the extraction technique used at this mine. The blasted waste rock from the open pit mine is simply dumped over the stopes being worked. As ore is extracted from the lower levels, this material falls in and fills the space. As it is constantly moving, this type of fill consolidates very little during mining operations.

Of course, since a surface pillar was left in the eastern part of the deposit, fill cannot be dumped directly on the surface.

In this case, it is brought underground into the stopes by a raise running right across the pillar.

As a general rule, conventional bolts about 8 ft (2.4 m) long have been used since the beginning of operations in this mine, but operators are increasingly adopting swellex type bolts 8 to 20 ft long (2.4 to 6 m) long. This type of anchor gives very satisfactory and more consistent results, in the opinion of personnel interviewed.

14.8 MONITORING PROGRAM(S)

. Stress Measurement

No stress measurements have been taken on the actual site of the property. Rock Mechanics Department personnel used data gathered at the nearest mining site. These values do, however, give a general idea of the magnitude of the stresses likely to affect the stability of this operation.

At level 5, that is about 1 000 ft (305 m) beneath the surface, the vertical stress is about equal to the weight of the rock, i.e. around 1 000 psi (6.9 MPa). The principal horizontal stress striking NS, would be about 2.5 times higher than the vertical stress. The intermediate stress would strike EW (in the direction of the longitudinal axis of the deposit) and would be 1.5 times greater than the vertical stress.

These interpretations were later confirmed by observation of the behaviour of the underground drifts and raises. The scaling in the walls of these openings and the way ruptures occur indicate that the damage is caused by a horizontal stress.

Even though the absolute value of this stress is low, i.e. around 2 500 psi à 1 000 ft in depth (17.2 MPa à 300 m), its relative importance in such schistous rock is high.

. Displacement Measurement

Displacement measurements were taken to determine the extent of the subsidence noticed in the hanging wall of the deposit, on the side of the surface installations, where the unconsolidated fill permits relaxation of this sector. The rib pillars control displacement of the wall by reducing the span of unsupported zones. The greatest displacements therefore occur between these.

The mine has had problems with the multiple anchored extensometers installed underground. Apparently these problems were related to the reliability of the readings. It was thus decided to install on the surface, a network of fifteen (15) bars anchored to the rock, measured periodically and set along three (3) principal lines as shown in Figure 14.1. The operators evaluated the probable angle of susbidence theoretically. Thus with an angle of 70° from horizontal and from 1 000 ft (300 m) below the surface, the soil located at more than 360 ft (110 m) from the exploitation zone should not move.

. Other Program(s)

A drift provides access below the surface pillar of the eastern sector of #3 zone. This pillar has therefore been inspected visually on occasion.

Also, a year and a half after the mining of the underlying stope, a drill hole was made through this pillar, allowing confirmation of its thickness at ± 5 ft (1.5 m).

14.9 SURFACE PILLAR DESIGN

. Personnel Involved

This operation has a Rock Mechanics section as part of its Engineering Group. However, design of excavations or pillars is done in collaboration with the Geology and Operations Departments (see Figure 14.5). The neccessity of insuring stability of the stopes and the economic value of the ore are the criteria used for sizing. The Company uses the services of a consulting firm on an annual basis.

. Chronology

The original surface pillar left in the eastern part of zone #3 has not been modified.

. Design Factors

It appears that the sizing of the surface pillar has been based on the decrease in the grade of economic ore. They did say, however, that as a general rule the thickness of the pillar should be about twice its width.

As shown in the cross-section in Figure 14.6, if the mining of the stopes of zones #1 and #3 (which meet in this sector of the mine) is taken into account, the total width affected by the excavations is about 75 ft (23 m). The surface pillar left over this zone is 138 ft (42 m) or about twice this width.

ORGANIZATION CHART - PILLARS DESIGN
ORGANIGRAMME - CONCEPTION DES PILIERS

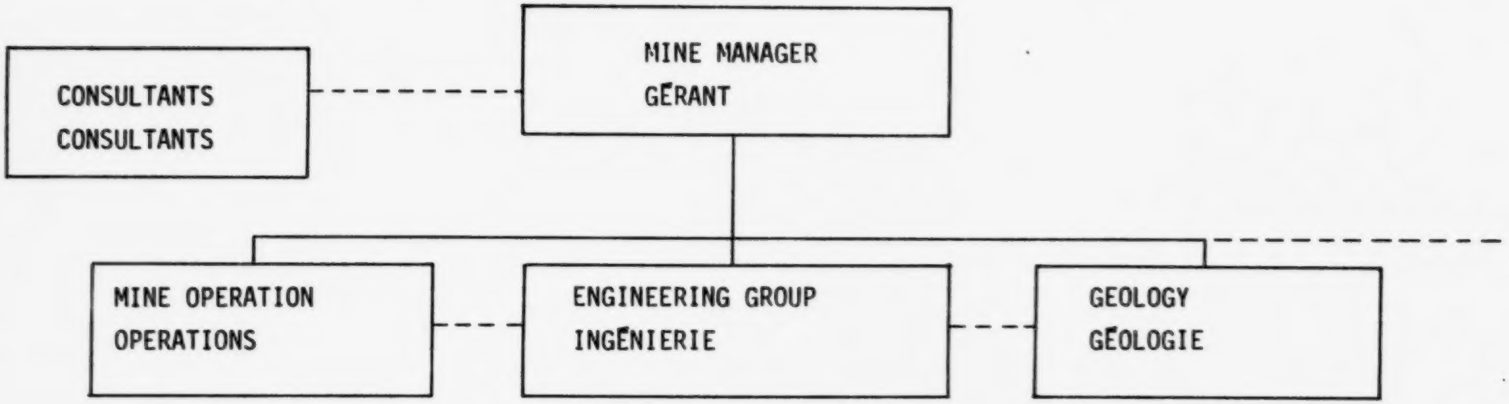

MINE MANAGER
GÉRANT
CONSULTANTS
CONSULTANTS
MINE OPERATION
OPERATIONS
ENGINEERING GROUP
INGÉNIERIE
GEOLOGY
GÉOLOGIE

Figure 14.5

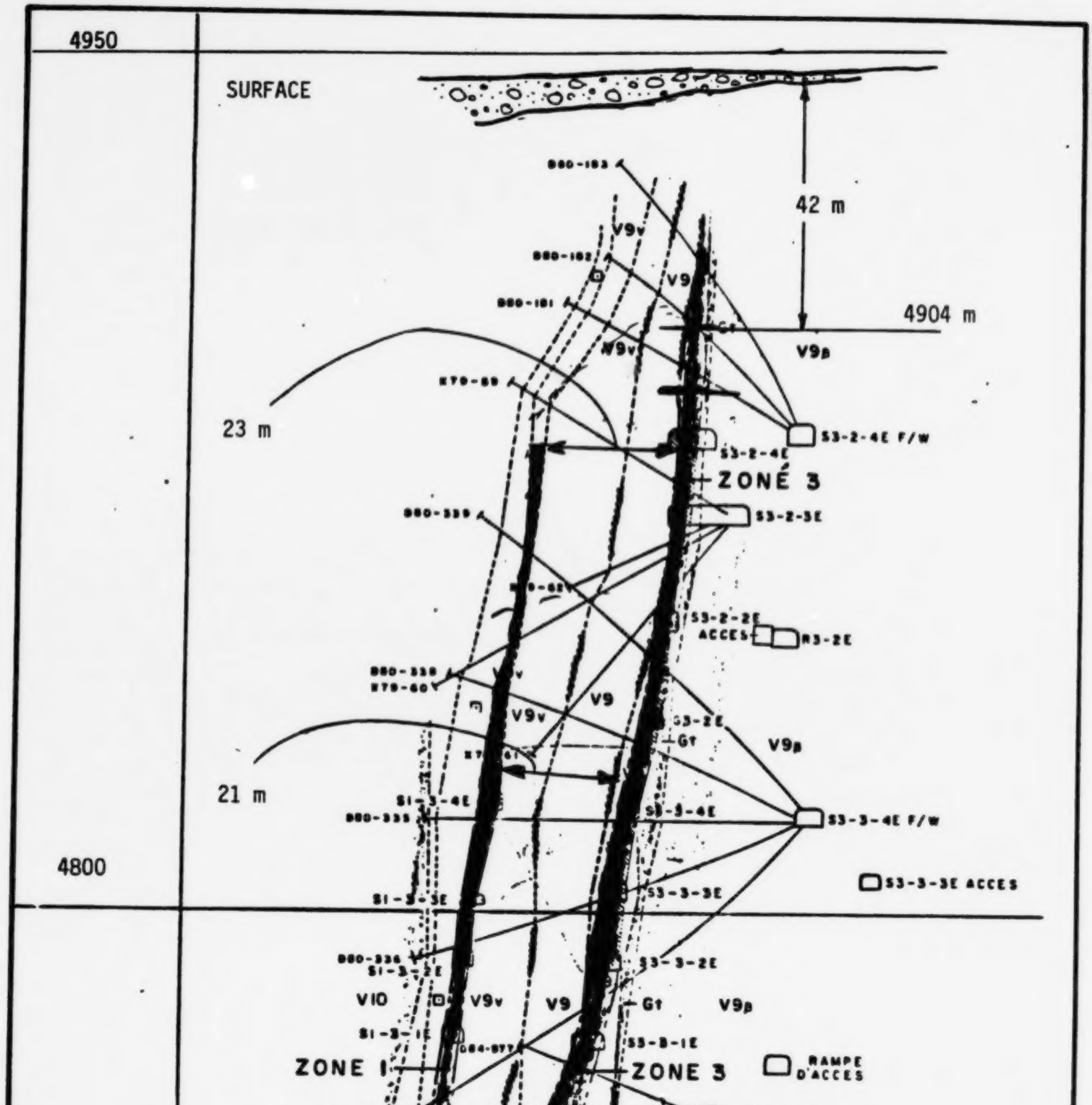

4950
SURFACE
42 m
4904 m
V9v
V9
V9p
23 m
S3-2-4E F/W
S3-2-4E
ZONE 3
S3-2-3E
S3-2-2E
ACCES
R3-2E
V9v
V9
S3-2E
Gt
V9p
21 m
S1-3-4E
S3-3-4E
S3-3-4E F/W
4800
S3-3-3E ACCES
S1-3-3E
S3-3-3E
S1-3-2E
S3-3-2E
V10
V9v
V9
Gt
V9p
S1-3-1E
S3-3-1E
ZONE 1
ZONE 3
RAMPE D'ACCES
G3-3E ACCES
G3-3-02

Fig. 14.6 Coupe A-A' Section

Scale - échelle
1: 1000

Initially, zone #1 and #2 were worked without being filled. A year and a half later, a raise was built on the surface to facilitate the filling of the stopes. At this time, a drill hole had confirmed that the thickness of the surface pillar had remained unchanged.

A few years ago, it appears that the rock (composed of sericitic schist of low competence) situated between exploitation zones #1 and #3 caved in. This caused damage at deeper levels, but did not affect the surface pillar. This landslide occurred during the snow melt (evidence of the major role played by water in the stability of this type of ground).

. Pillar Dimensions

The dimensions of the only surface pillar are compiled in Table 14.2.

DIMENSIONS OF SURFACE CROWN PILLARS

DIMENSIONS DES PILIERS DE SURFACE

TABLE 14,2
TABLEAU 14,2

DIMENSIONS		PILLARS - PILIERS							
		#1							
. THICKNESS: EPAISSEUR:									
- WATER BODY PLANS D'EAU	feet-pi. (m)	-							
- OVERBURDEN MORTS-TERRAINS	feet-pi. (m)	15 (4,6)							
. SURFACE CROWN PILLAR: PILIER DE SURFACE:									
- THICKNESS EPAISSEUR	feet-pi. (m)	140 (43)							
- WIDTH LARGEUR	feet-pi. (m)	75 (23)							
- LENGTH LONGUEUR	feet-pi. (m)	330 (100)							
- THICKNESS/WIDTH RATIO RAPPORT EPAISSEUR/LARGEUR		1,9							
. STOPE HEIGHT HAUTEUR DU CHANTIER	feet-pi. (m)	370 (113)							
. FILL HEIGHT HAUTEUR DU REMBLAI	feet-pi. (m)	370 (113)							

14.10 VISUAL EVALUATION OF SURFACE PILLAR(S)

A visit of upper levels in the mine, in the eastern sector of zones 1 and 3, gave access to the extremity of the stope situated below the surface pillar where the a schistosity of the walls is such that the R.Q.D. value is about 10%. It is noticeable that the lighest part of this stope in only slightly supported by the rock fill. The fill, flowing out from the raise situated approximately at the middle of the length of the stope, forms an angle of rest of about 40°. Thus the stability of the pillar is much more influenced by the stress redistribution and the strength (even slight) of the rock mass than by the presence of the fill. Naturally, the fill controls scaling in the walls and slows the deterioration process.

In this sector, there is little evidence of water infiltaration but its presence is obvious in the drawing drifts where the sericite formed turns easily to mud.

This is a situation where it is practically impossible to judge the stability or the reaction of the rock mass without the use of instrumentation.

14.11 MANAGEMENT'S COMMENTS

The Company is obviously concerned by research work on bolting. In a material so schistic, the importance of local support is evident.

The Company also considers the mechanization of development work of primary importance in reducing the cost of stope preparation.

Finally, the control of water infiltration in the mine is an important element at this property. They would thus appreciate any research in this area.

MINE #15

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15.0 SUMMARY OF THE VISIT

The southern vein of this property is located within metavolcanic rocks generally of good competence. The deposit is covered with about 100 ft (30 m) of sand and gravel and is bissected by a sizeable aquifer, 5 to 6 in wide (13 to 15 cm); this aquifer can put out as much as 200 (I) GMP (15 L/s) when intersected by a 9 x 8 ft drift (2.7 x 2.4 m).

The Company is still in the development and pilot stope stage. However, data on the rock and its behaviour are accumulating little by little. From a rock mechanics standpoint, the zone of interest lies in the vein of quartz about 30 ft (9 m) into the two walls (particularly in the hanging wall). The vein/wall interfaces are often graphitic and schistic.

The Company expects to exploit this zone using the blasthole method with stopes 130 ft (39 m) long by 66 ft (19.8 m) high and an average of 16 to 20 ft wide (4.8 to 6 m).

This case history puts a much greater accent on the description of a particular geological context than on an example of surface pillar design as such.

15.1 GENERAL INFORMATION

. Regional Geology

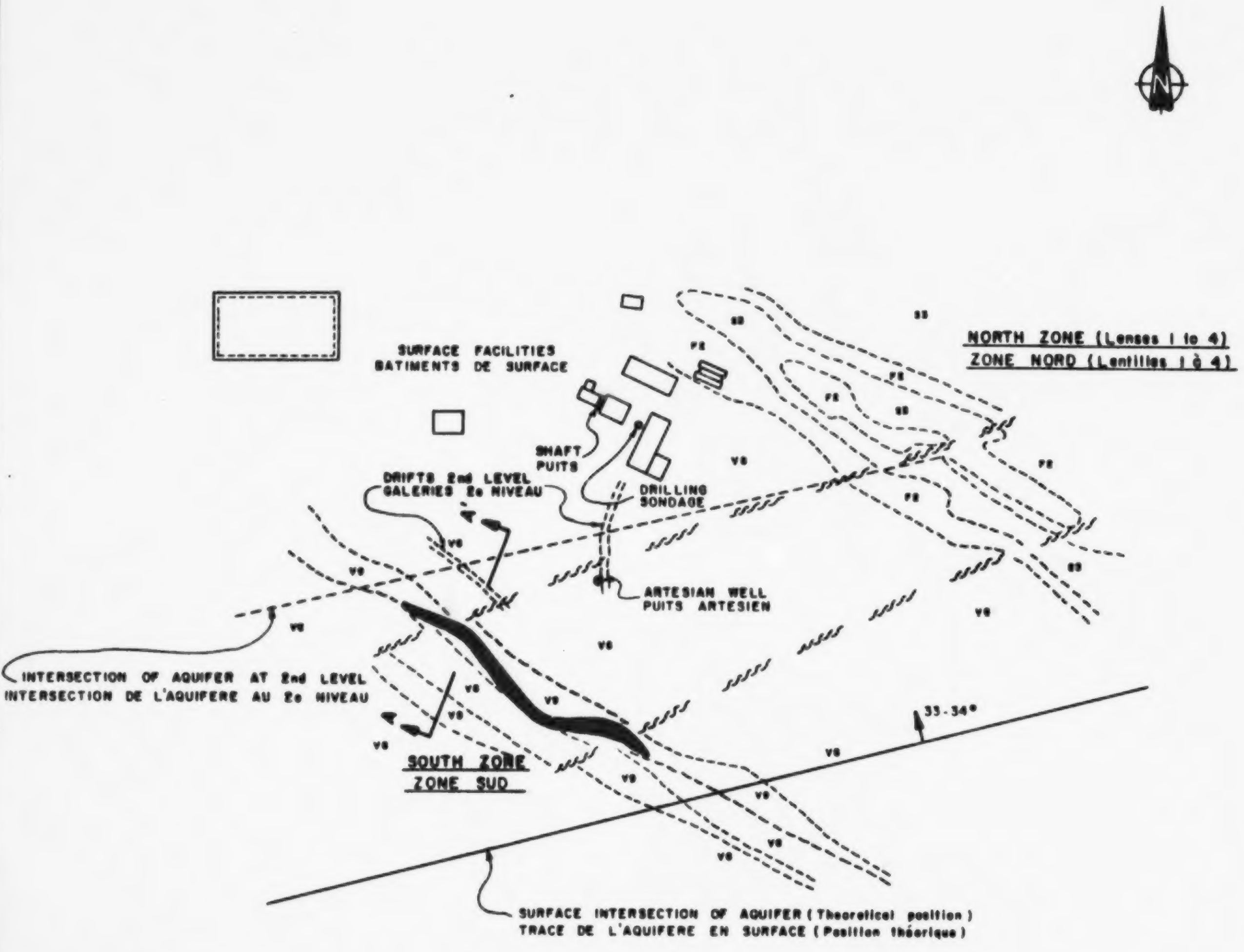
The property is located in the Superior Province at about fifteen kilometers from Greenville in the northern part of a large geosyncline. It is situated in a sequence of metasedimantary rocks (graywacke, argillite) and metavolcanic rocks (basalt, andesite). All these rocks are of Archean age and the regional metamorphism is amphibolite facies with garnet.

. Local Geology

The ore zones are grouped in the northern and southern sectors of the property. For this study we elected, however, to restrict ourselves to the southern sector where an alternation of adesite and tuffs is found. The units generally strike NW-SE and dip 70 to 80° to the north west. The andesite, generally massive, is present in both walls of the deposit. The line of tuff is for the most part well-layered, competent and contains ore.

. Deposit Characteristics

The south zone is composed of a lense or vein of quartz changed to gold by mineralization. Figures 15.1 and 15.2 show both the property as a whole and the study area situated in the south part. This lense follows the same axis as the local geological units and has the following characteristics:


SURFACE FACILITIES
BATIMENTS DE SURFACE
SHAFT
PUITS
DRILLING
SONDAGE
DRIFTS 2nd LEVEL
GALERIES 2e NIVEAU
ARTESIAN WELL
PUITS ARTESIEN
NORTH ZONE (Lenses 1 to 4)
ZONE NORD (Lentilles 1 à 4)
SOUTH ZONE
ZONE SUD
INTERSECTION OF AQUIFER AT 2nd LEVEL
INTERSECTION DE L'AQUIFERE AU 2e NIVEAU
SURFACE INTERSECTION OF AQUIFER (Theoretical position)
TRACE DE L'AQUIFERE EN SURFACE (Position théorique)
33-34°
N
S3
F2
V6
V9

LEGEND - LEGENDE

■	Lense south zone Lentille zone sud
F2	Iron formation Formation de fer
S3	Grouwacke
V6	Andesite Andésite
V9	Tuff Tuf

METERS - METRES

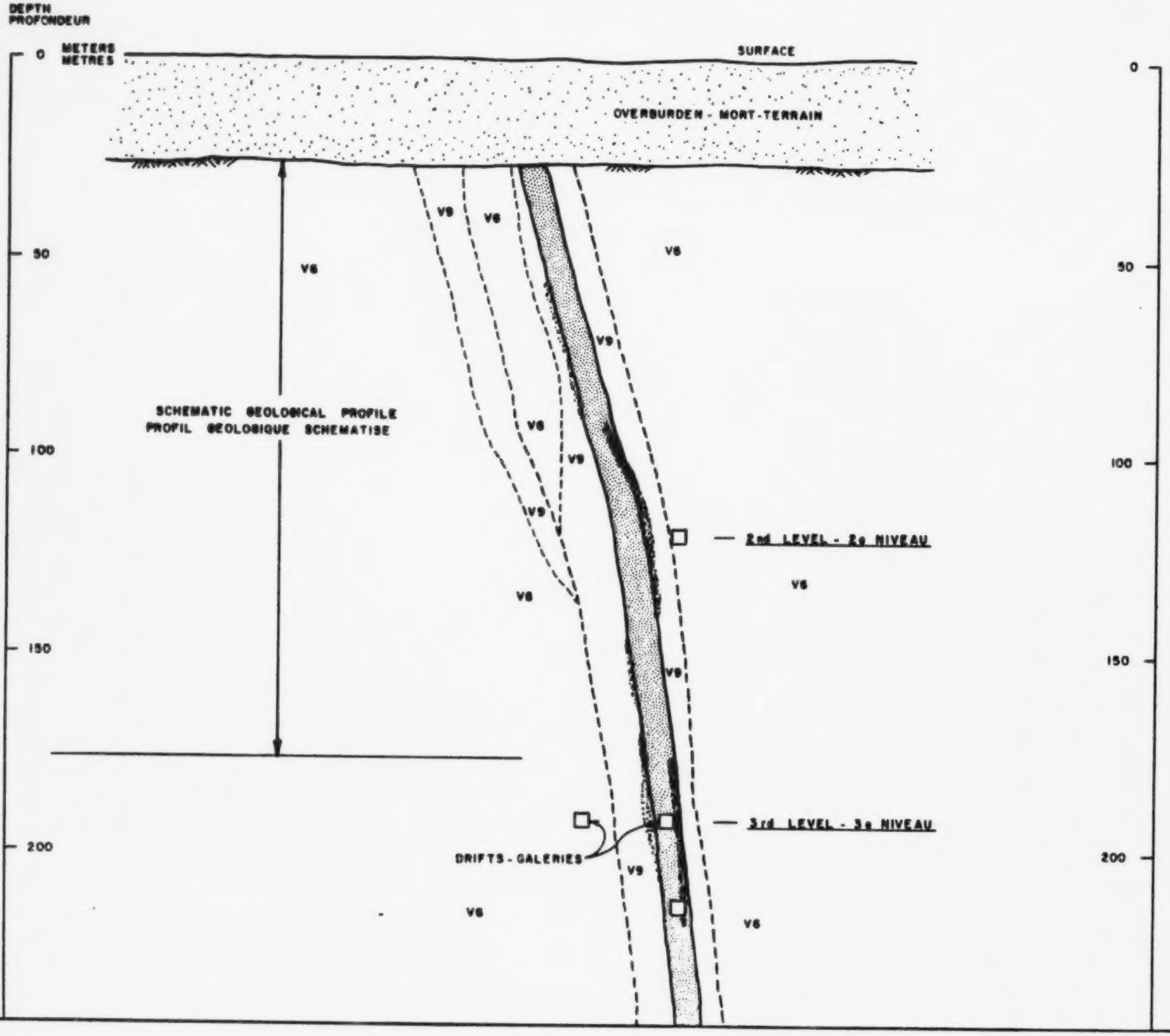
ROCHE

Groupe conseil

MINE #15 MINE

SURFACE PLAN
PLAN DE SURFACE

Date	Figure
08/85	15.1


DEPTH
PROFONDEUR
METERS
METRES
0
50
100
150
200
SURFACE
OVERBURDEN - MORT-TERRAIN
SCHEMATIC GEOLOGICAL PROFILE
PROFIL GEOLOGIQUE SCHEMATISE
V6
V9
2nd LEVEL - 2e NIVEAU
3rd LEVEL - 3e NIVEAU
DRIFTS - GALERIES

LEGEND - LEGENDE

▨	Ore zone Zone minéralisée
▨	Graphite horizon Horizon de graphite
V6	Andesite Andésite
V9	Tuff Tuf

0 10 20 30
METERS - METRES

SECTION
COUPE
A - A'

ROCHE
[illegible]
Groupe conseil

[illegible]

MINE # 15 MINE

GEOLOGICAL SECTION
COUPE GEOLOGIQUE

Date	Figure
08/85	15.2

Length	Width	Depth
850 ft	16-23 ft	Undetermined
(260 m)	(5-7 m)	

The dip is about 70° to 80° north west. This sector of the mine is currently under development but a certain amount of information is available. In order to evaluate the general context in which future surface pillar(s) will be established, it is necessary to make certain hypotheses as to the form and the characteristics of the upper part of this vein while keeping to geomechanical parameters. Thus what we are describing is more a context than a precise and verifiable reality.

15.2 MINE ENVIRONMENT

The mine is located outside the zones already exploited by the Company, in an isolated area hitherto untouched. The rock base is covered by about 100 ft (30 m) of overburden.

There is no infrastructure in the neighbourhood of this mine: that is, at less than 500 ft (150 m).

15.3 OVERBURDEN

. Studies

A geotechnical study of the soil was done in the area of the mine shaft at about 500 ft (150 m) from the zone under study.

The results of this series of test holes are probably more or less representative of the composition of the overburden covering the southern vein. The relief of the region is relatively flat and uniform. Also, the digging of an artesian well about 160 ft (48 m) from the vein ran through the same formations and reached the rock at 100 ft (30 m) deep. A group of five (5) drill holes also confirms the position of the rock in this sector.

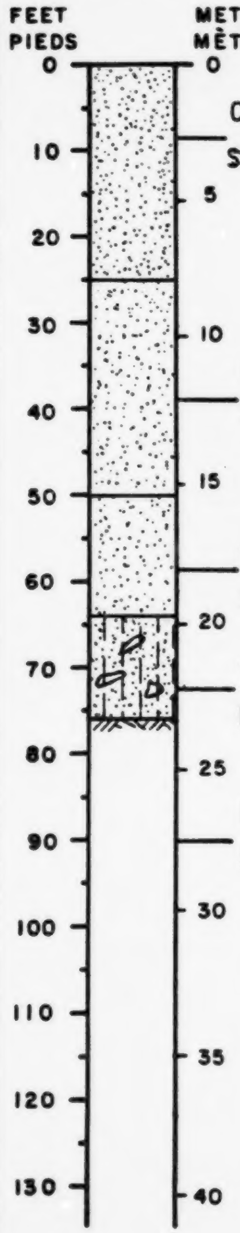
. Stratigraphy and Characteristics

Figure 15.3 shows the overburden generally composed of a thick deposit of granular material of density increasing with depth. The layer of moraine at the contact point with the base rock is thus qualified as very dense. These soils have, however, only a very slight capacity for self-support and can cave-in should the surface pillar be lost.

At this stage of analysis, the average characteristics of the soils can be described as follows:

Porosity	:	30 - 34%
Water content	:	16 - 19%
Unit weight (saturated)	:	2.16 - 2.09

SOIL STRATIGRAPHY
STRATIGRAPHIE DU SOL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15
20
25
30
35
40

	PENETRATION INDEX INDICE DE PÉNÉTRATION
Compact, uniform fine to medium sand Sable compact, fin à moyen, uniforme	N = 10-20
Compact silty fine to medium sand Sable compact, fin à moyen, traces de silt	N = 30-40
Dense fine sand - Sable fin, dense	N = 40
Very dense silty sand, occasional cobble Moraine sablonneuse à blocaux	N = >40
Bedrock Socle rocheux	

Note: Borehole located near the shaft (see fig.15.1)
Sondage à proximité du puits (voir fig. 15.1)

ROCHE associés ltée Groupe-conseil 2535, boul Laurier, Sainte-Foy, Québec G1V 4M3 Canada (418) 871 9800 Télex: QBC 051 31583	**MINE # 15 MINE**	**Date** 07-1985	**Figure** 15.3

15.4 ROCK MASS

. Nature of the Rock

The footwall is composed of fine-grain andesite generally present at about 35 ft (10.5 m) from the vein of mineralized quartz. This metavolcanic rock is competent; it contains at least three (3) families of tight joints (not yet mapped) and shows variable degrees of amphibolization.

In immediate contact with the vein, high schistosity tuffs parallel to the dip of the deposit contain layers of chert and becomes graphitic. Though normally of good competence, it becomes schistic, folded and altered near the auriferous vein.

The vein, composed of smoky grey quartz, is dotted with numerous micro-fractures filled with carbonate, chlorite, sericite or graphite.

The same rock sequence (tuff and andesite) is found farther along in the hanging wall of the deposit.

. Structural Geology

The Company does not yet have on hand the necessary elements for a precise definition of the structure of the rock mass. Test drills have, however, made it possible to interpret at least two (2) main faults striking NE-SW and located in the extremities of the vein. The schistosity is very pronounced and is parallel to the dip of the deposit.

. Characteristics

Data on the geomechanical properties of the different rocks are not presently available. The average densities of the ore zone and of the andesite are 2.6 and 2.8 respectively.

However, the most important characteristic of this zone is the poor quality of the ore/wall interface. The vein of quartz, with a strength varying from 15 to 20 psi, is usually bounded by graphitic contacts. The thickness of the graphite veins runs from a few inches to as much as five feet (1.5 m). With no quantifiable data on hand, one may assume that the friction coeffecient is, for all practical purposes, nil between the vein of quartz and the walls. Should graphite prove to be present in the upper level of the zone, this element will become a key factor in the design of an eventual surface pillar.

15.5 HYDROGEOLOGICAL CONDITIONS

. Overburden

The original water table was discovered at about 50 ft (15 m) below the surface of the soil by a drill hole located close to the shaft. Because of the topography, it is safe to assume that above the zone under study, the water table is situated at about the same elevation.

. Rock Mass

The development drifts intercept a sizeable aquifer zone on several levels of the mine. This aquifer follows a N76°E direction with a 33°NW dip. Available data on the position of the aquifer at different levels makes it possible to establish the theoretic equation of the plane as a function of the N-S coordinates and the elevation of any point; it thus becomes easy to locate the aquifer.

This zone has a thickness varying from 4 to 6 in (10 to 15 cm) and contains highly altered carbonates. It is safe to assume that most of the water pumped from the mine comes from the aquifer. At the second level alone, about 200 (I) GPM (15 L/s), (or 25% of the total volume of water pumped) originates from this zone.

The following are conclusions reached on the basis of analysis of the situation conducted by mine authorities:

- The feed source is very substantial
- Water flows freely in the aquifer
- There is fear that erosion of the carbonates is causing the increase in flow.

The position of the aquifer was also confirmed by the drilling of the artesian well located on Figure 15.1. This well runs through both the overburden and the upper layer of rock to a depth of 300 ft (90 m) and is above the plane of the aquifer. A large amount of water was encountered at 256 ft (78 m) below the surface, corresponding to the theoretic position of the aquifer.

It should be noted, however, that this well no longer produces water. The water table, originally 50 ft 15 m) below the surface, has receded around the artesian well which appears to be draining into the aquifer.

Mine personnel also indicated that the rate of infiltration in the mine has been increasing steadily over the last year in proportion to the number of development drifts opened underground. It is currently at about 740 (I) GPM (56 L/s) in all.

On a local scale, i.e. around the drifts or the drill holes crossing the aquifer, operators have managed to reduce water infiltration considerably using shotcrete. This seems to be an efficient technique on a local level but no overall solution is being considered at the moment.

15.6 MINING OPERATIONS

. Mining Method(s)

In the case of this property, no particular method of exploitation has been definitively chosen. The Company is continuing development of drifts on several levels and expects to begin a pilot stope in the near future. The latter will have the following characteristics:

- Long hole blasting
- Length: 130 ft (40 m)
- Height: 66 ft (20 m)
- Width: 16 to 20 ft (5 to 6 m)

. Operating Conditions

The operation's parameters are also still under study. With respect to the surface pillar, no exploitation will be (for the moment) above level 3, that is less than 500 ft (150 m) from the rock/soil interface.

15.7 SUPPORT AND REINFORCEMENT METHODS

. Primary Support

It is too soon to say what technique will be adopted.

. Filling and reinforcment

Outside the area of influence of the vein of quartz in the andesite and the tuff, the access drifts of 8 x 9 ft (2.4 x 2.7 m) need little support; locally conventional bolts of 5 ft (1.5 m) are in use.

However, in immediate contact with the vein, as far as 13 to 17 ft (4 to 5 m) into the hanging wall, the schistic and graphitic rock has a tendancy to break up requiring tight bolting, often accompanied by steel mesh.

The vein itself has been cut longitudinally at several levels and sub-levels. The presence of micro-fissures filled with the product of alteration causes localized problems of roof stability. The roof does not support itself well when the span exceeds 15 ft (4.6 m). The operators used wooden frames to shore the roof in a section of level 3.

15.8 MONITORING PROGRAM

At the moment, this aspect of the operation is still to be determined.

15.9 SURFACE PILLAR DESIGN

. Personnel Involved

This property is relatively small and is in its initial stages. The development and exploitation planning is the responsability of the on-site personnel, chiefly the Mine Engineer under the supervision of the Directors of Geology and Exploitation (Fig.15.4).

. Chronology

The Company is just beginning the study of this zone. It expects to proceed by stages as follows:
- Evaluation of the aquifer zone
- Geotechnical drilling at the surface
- Geomechanical study

The information thus gathered will be used in the eventual design of the surface pillar.

. Design Factors

Does not apply in this case.

. Pillar dimensions

Does not apply in this case.

ORGANIZATION CHART - PILLARS DESIGN
ORGANIGRAMME - CONCEPTION DES PILIERS

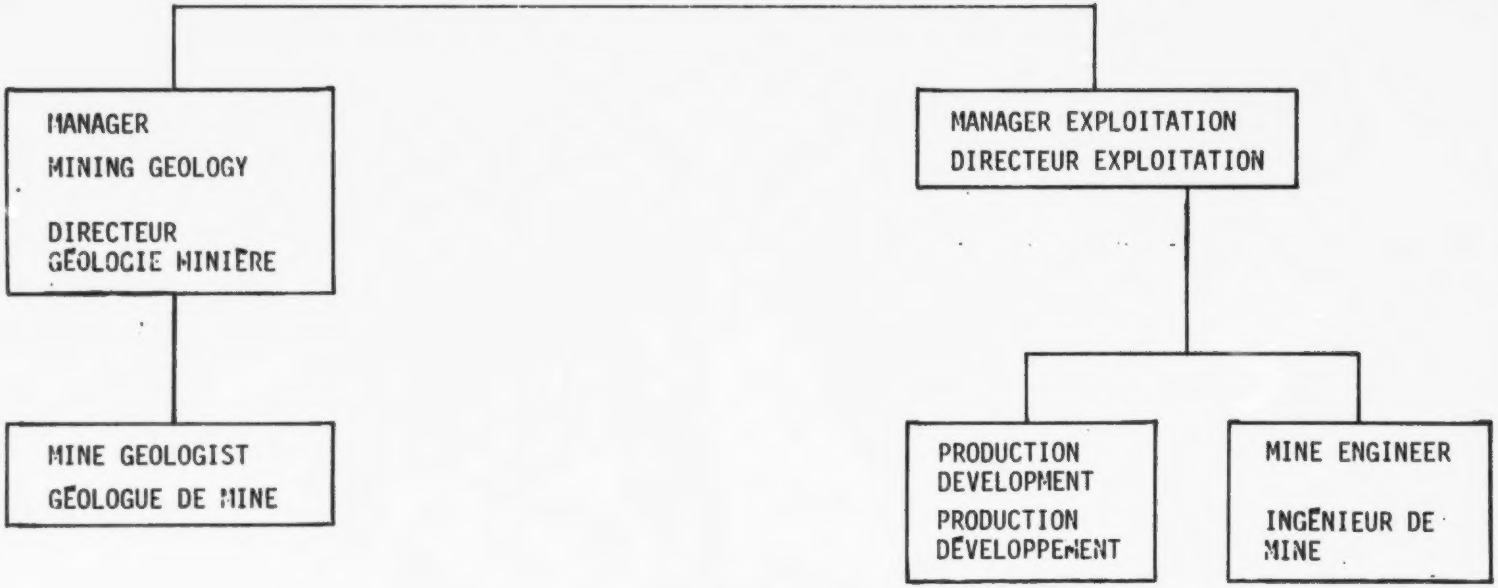
MANAGER
MINING GEOLOGY
DIRECTEUR
GÉOLOGIE MINIÈRE
MANAGER EXPLOITATION
DIRECTEUR EXPLOITATION
MINE GEOLOGIST
GÉOLOGUE DE MINE
PRODUCTION
DEVELOPMENT
PRODUCTION
DÉVELOPPEMENT
MINE ENGINEER
INGÉNIEUR DE
MINE

Figure 15.4

15.10 VISUAL EVALUATION OF THE SURFACE PILLAR(S)

Our visit to the drifts in the southern zone of the operation naturally did not allow us to observe the area of the surface pillar which has been inaccessible up to now.

However, the Mine Geologist informed us that in his opinion, it is plausible to assume a continuity of the geological structures as far as the rock/overburden interface (without referring to the grade or the value of the ore zone).

Outside the ore zone, the rock is very competent. We estimate the R.Q.D. value at 80% or more, exception made for a drift that crosses the aquifer or a major fault. Stability problems increase at about 30 ft (9 m) from the ore zone where R.Q.D. values decrease progressively, almost to 0 in some places where the rock becomes schistic or graphitic.

As to the gold-bearing zone, (the quartz vein), it appears to be very competent and has few fractures. However, as already pointed out in the chapter on support, it has a tendancy towards tensile failure when the roof span is more than 15 ft (4.5 m). The rock's own weight and the effects of the blasting are likely responsible for this.

15.11 MANAGEMENT'S COMMENTS

The mine's management is looking for economically profitable solutions. They would appreciate any diffusion of technical information in the areas of hydrogeology or rock mechanics as applied to mines of low tonnage ($\approx$500 000 tons). The economics aspect of the studies is considered to be very important.

MINE #16

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- Characteristics of the Deposit

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- Stratigraphy and Characteristics

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- Design Factors
- Pillar Dimensions

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16.0 SUMMARY OF THE VISIT

The deposit is composed of metavolcanogenic and volcanogenic massive sulfides, mineralized in the form of zinc, lead, silver, copper and small quantities of gold. The shape of the deposit is complex because of the influence of four (4) phases of deformation. The ore rises right to the surface and has an average dip of 75°. The walls are composed of metasediments.

The overburden has been removed from about 2/3 of the length of the deposit. The soil is composed of sand and glacial gravel lying on a gossan type oxidized zone ranging from 25 to 40 ft (8 to 12 m).

The surface pillars have been partially worked. Exploitation of the ore zone located between 0 and 500 ft (152 m) has been carried out using four different methods; descending from the surface, these methods were open pit mining for the north part of the deposit, the "avoca" method, the cut-and-fill method and the open stope blasthole method.

During the open pit operation, the central part of the rock mass covering the deposit caved-in into the underlying open stopes. Following this incident, exploitation of the upper stopes was stopped and these were filled in with waste rock from the surface. Partial exploitation of the upper stopes was only resumed after five years.

The initial design of the surface pillar was based on the following equation:

Thickness of the surface pillar = 3 x width of the underlying stopes

16.1 GENERAL INFORMATION

. Regional Geology

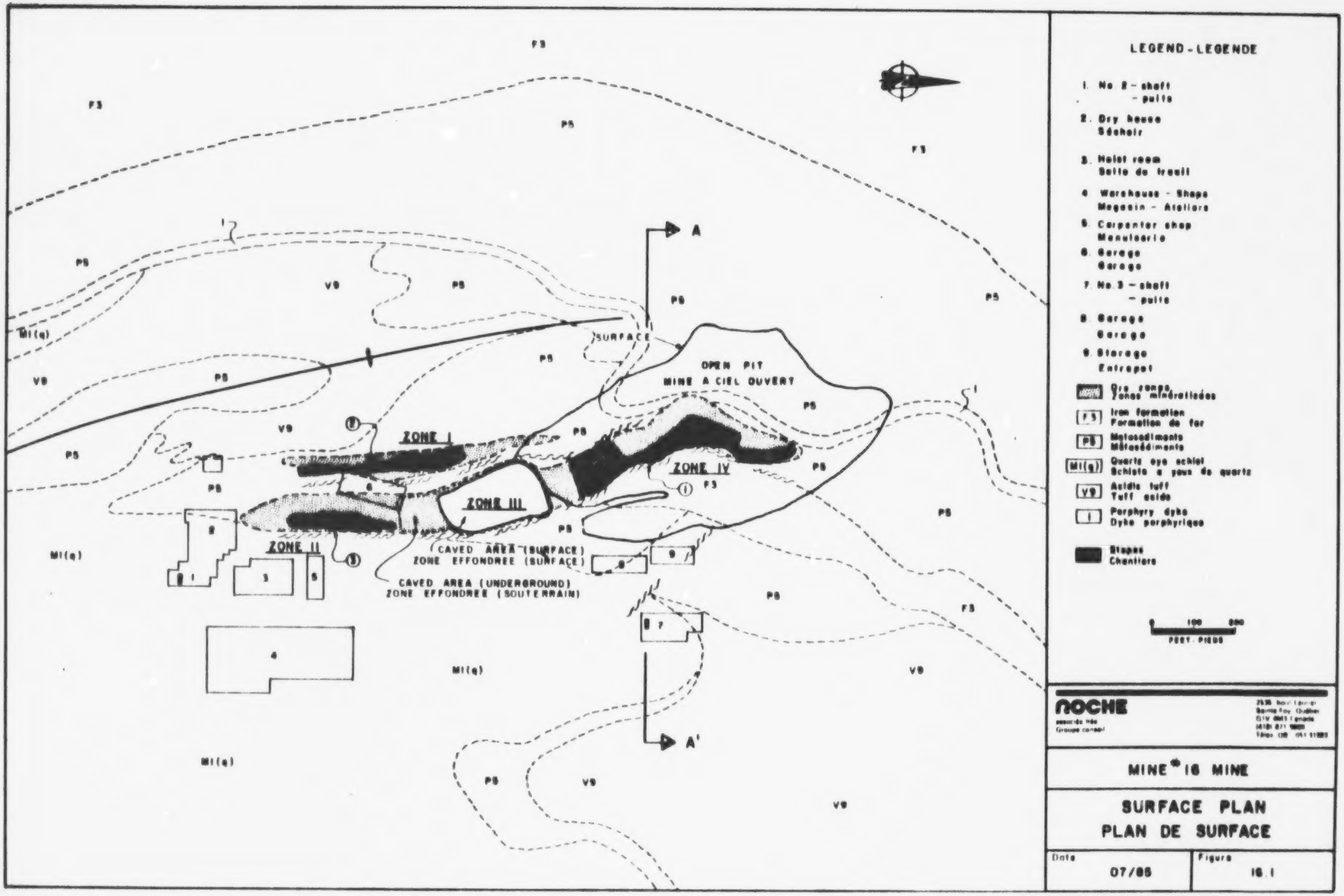
The region is typified by a belt of folded rock composed of Ordovician and volcanic sedimentary units located in the orogenic zone of the Appalachians. This rock was metamorphozed (green schist facies) and very deformed during the Taconic and Acadian Orogenies. A granite intrusion of Devonian origin and sedimentary layers from the Pennsylvanian period border the Ordovician rock to the east.

. Local Geology

Four (4) phases of deformation have been identified in this mining region. These deformations caused the separation of a deposit of massive sulfides into four zones separated by metasediments. These massive sulfides are situated between graywacke containing argillite and very schistic argillite changing gradually to massive argillite. Basic volcanic rocks, a formation of iron, siliceous tuff, chloritized metasediments and quartz eye schists are found in the vicinity of the ore. (See figures 16.1 and 16.2).

. Characteristics of the deposit

The deposit is composed of metavolcanogenic and volcanogenic massive sulfides containing zinc, lead, silver, copper and small quantities of gold. The shape of the deposit, as previously mentioned, is complex because of the phases of deformation that changed the original


F3
P5
V9
MI(q)
A
A'
SURFACE
OPEN PIT
MINE A CIEL OUVERT
ZONE I
ZONE II
ZONE III
ZONE IV
CAVED AREA (SURFACE)
ZONE EFFONDREE (SURFACE)
CAVED AREA (UNDERGROUND)
ZONE EFFONDREE (SOUTERRAIN)
1
2
3
4
5
6
7
8
9
LEGEND - LEGENDE
1. No. 2 - shaft
- puits
2. Dry house
Séchoir
3. Hoist room
Salle de treuil
4. Warehouse - Shops
Magasin - Ateliers
5. Carpenter shop
Menuiserie
6. Garage
Garage
7. No. 3 - shaft
- puits
8. Garage
Garage
9. Storage
Entrepot
Ore zones
Zones minéralisées
F3 Iron formation
Formation de fer
P5 Metasediments
Métasédiments
MI(q) Quartz eye schist
Schiste a yeux de quartz
V9 Acidic tuff
Tuff acide
I Porphyry dyke
Dyke porphyrique
Stopes
Chantiers
0
100
200
FEET - PIEDS
ROCHE
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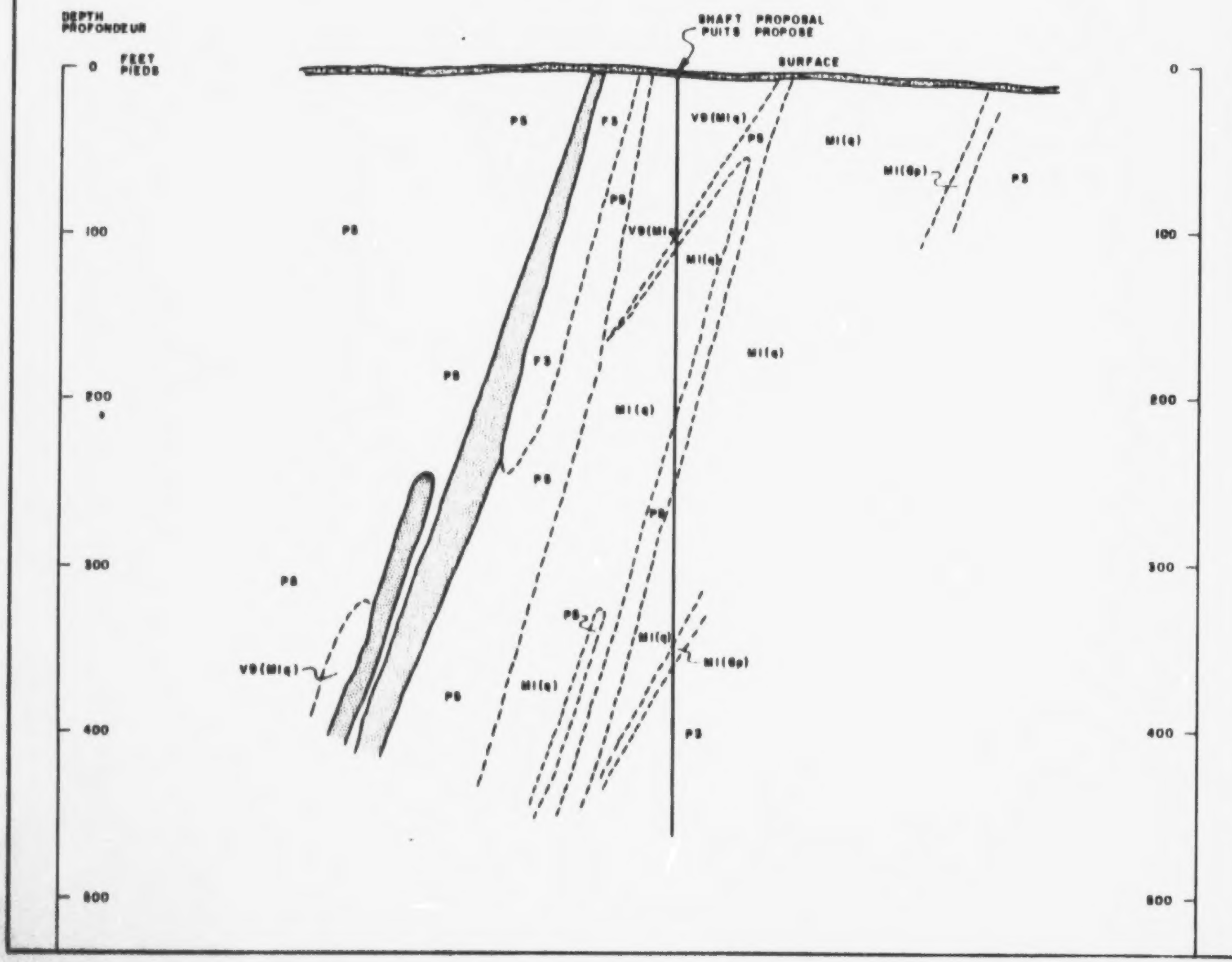
MINE ® 16 MINE

SURFACE PLAN
PLAN DE SURFACE

Date 07/85

Figure 16.1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SHAFT PROPOSAL
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P3
V9(MIq)
Ml(q)
Ml(Gp)
P3
P5
Ml(q)
Ml(Gp)
P3

LEGEND - LEGENDE

▨ Ore zones
Zones minéralisées
P3 Iron formation
Formation de fer oxidé
V9(MIq) Cristal tuff and QES XT
Tuff à cristaux de quartz
Ml(q) Quartz eye schist
Schiste à yeux de quartz
Ml(Gp) Graphite Schist
Schiste à graphite
P3 Graywacke
P5 Metasediments (mostly argillite)
Métasédiments (surtout argillite)
0 250 500
FEET · PIEDS

SECTION A-A'
COUPE

NOCHE
Groupe conseil

MINE # 16 MINE

GEOLOGICAL SECTION
COUPE GEOLOGIQUE

Date 06/88

Figure 16.2

state of the deposit. The average dimensions of the deposit and its principal characteristics are:

Length	Width	Depth
1 300 ft	150 ft	3 700 ft
(400 m)	(46 m)	(1 128 m)

The length and width of the deposit increase with depth. Production is continuous at about 10 500 t per day.

16.2 MINE ENVIRONMENT

There are a few buildings in the area over the surface pillars, in particular a garage located just above the upper stopes of the southern part of the mine (see Figure 16.1). To the north, the deposit has been partially worked from an open pit. During the exploitation of the second pit, there was a cave-in in the principal ore zone, between the open pit operation and the western part of the deposit. After the cave-in, the open pit operation was stopped and the caved-in area filled in order to stabilize this part of the terrain.

The shafts are located about 300 ft (91 m) from the upper stopes. No other underground mine is located in the vicinity of the mine visited.

16.3 OVERBURDEN

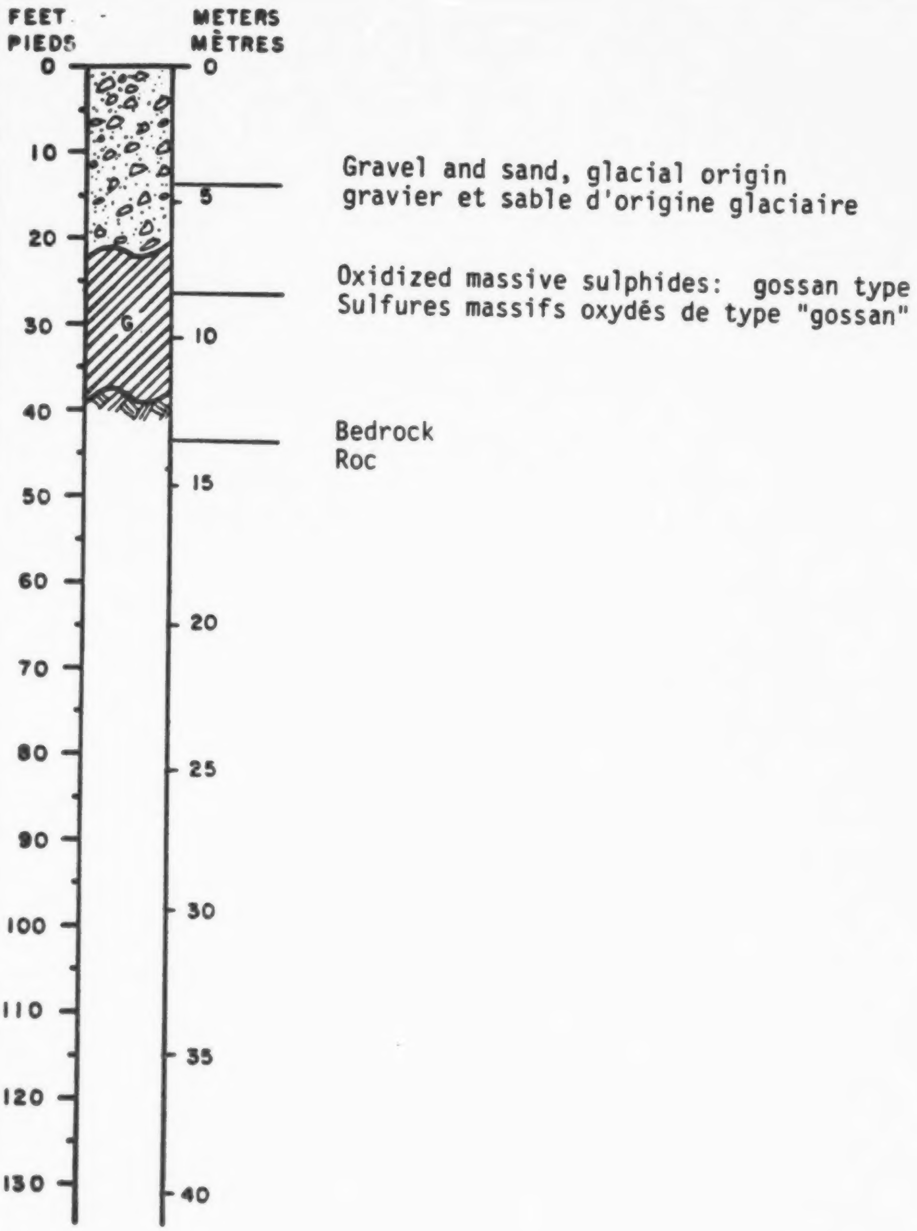
. Studies

No geotechnical study has been conducted on the soil covering the surface pillars. The overburden has been removed from about two-thirds (2/3) of the length of the deposit and a visual study of the soil was carried out during this work.

. Stratigraphy and Characteristics

The soil covering the mine is made up mainly of gravel and sand of glacial origin. Below this soil is a gossan-type oxidation zone in the upper part of the massive sulfides at the overburden/rock mass interface. The thickness of the soil and of the oxidized zone varies from 25 to 40 ft (8 to 12 m). (See Figure 16.3)

SOIL STRATIGRAPHY
STRATIGRAPHIE DU SOL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G
Gravel and sand, glacial origin
gravier et sable d'origine glaciaire
Oxidized massive sulphides: gossan type
Sulfures massifs oxydés de type "gossan"
Bedrock
Roc

ROCHE associés ltée Groupe-conseil 2535, boul Laurier, Sainte-Foy, Québec G1V 4M3 Canada (418) 871 9800 Télex : QBC 051 31583	MINE # 16 MINE	Date 07-1985	Figure 16.3

16.4 ROCK MASS

. Nature of the Rock

The rock mass is as follows:

Footwall	:	metasediments and iron formation
Deposit	:	fine grain massive sulfides
Hanging wall	:	metasediments

The principal chemical alterations are silicification, chloritization and sericitization and their influence varies from one place to another.

. Structural Geology

Fault systems and shearing zones developed during the deformation phases mentioned in 16.1. Two major faults about 80 ft (25 m) apart cross parallel to the deposit. A complex of minor faults accompanies these two major faults. There is well developed schistosity, generally following the strike of the deposit.

Joints have a random orientation and are mainly located in the heavily folded zones. The opening of the joints is normally very small (0.03 in or 0.08 cm) and they are commonly filled with quartz and chlorite. According to mine management, water pressure in these joints is almost nil near the contact with the rock wall. In some areas the surface of the drifts may be damp.

Stress measurements taken at level 2 800 showed that the major horizontal stress is about double that of the vertical stress:

$\sigma h = 2\ \sigma v = 8\ 000$ psi (55 MPa)

The contact point between the walls and massive sulfides is clearly defined throughout the deposit.

. Characteristics

Some of the geometric characteristics or the rock mass are presented in Table 16.1. The massive sulfides have very high compressive strength. The compressive strength values come from standard tests conducted on twelve (12) samples of each type of rock. No systematic R.Q.D. rating was taken during the drilling campaigns.

ROCK CHARACTERISTICS

CARACTÉRISTIQUES DE LA ROCHE

TABLE 16.1

TABLEAU 16.1

LOCATION EMPLACEMENT		FOOT WALL ÉPONTE INFÉRIEURE	OREBODY GISEMENT	HANGING WALL ÉPONTE SUPÉRIEURE
ROCK TYPE TYPE DE ROCHE		METASEDIMENTS AND IRON FORMATION METASEDIMENTS ET FORMATION DE FER	MASSIVE SULPHIDE SULFURES MASSIFS	METASEDIMENTS METASEDIMENTS
DENSITY DENSITÉ		2.9 - 3.0	4.3	2.9 - 3.0
COMPRESSIVE STRENGTH RÉSISTANCE EN COMPRESSION	psi x 10^3 (MPa)	9 - 15 (62 - 103)	20 50 (138-345)	5 - 10 (34 - 69)
SHEAR STRENGTH RÉSISTANCE AU CISAILLEMENT	psi x 10^3 (MPa)	-	-	-
TENSILE STRENGTH RÉSISTANCE EN TENSION	psi x 10^3 (MPa)	-	-	-
POINT LOAD STRENGTH INDICE DE DOUBLE POINCONNEMENT	psi x 10^3 (MPa)	-	-	-
POISSON'S RATIO RAPPORT DE POISSON		-	0.2	-
YOUNG'S MODULUS MODULE DE YOUNG	psi x 10^6 (GPa)	4 - 12 (28 - 83)	15-30 (103-207)	4 - 10 (30 - 69)
RQD %		-	-	-
GEOMECHANICAL CLASSIFICATION CLASSIFICATION GÉOMÉCANIQUE		-	180-NGI estimated	-

16.5 HYDROGEOLOGICAL CONDITIONS

. Overburden

The overburden is normally dry except at the end of spring when the snow melts rapidly. No network of piezometers has been installed over the surface pillars.

. Rock Mass

There is very little water entering the mine and pumping of 300 (US)GPM (19 L/s) is sufficient to keep the mine dry.

No shotcrete has been used in the upper portion of the rock mass.

16.6 MINING OPERATIONS

. Mining Methods

Prior to 1969, above level 1 400, stopes were worked entirely by the open stope method. In order to decrease dilution, this method was replaced, in 1969, by the cut-and-fill method for most of the mining, except for the upper part of the surface pillars which were worked as open pits and by the "avoca" method.

. Operating Conditions

Originally, the upper part of the mine was worked with the open stope method. This zone is the area from level 1 400 to the surface. However, the upper stopes which began at level 300 were ended at level 200. The thickness of the surface pillars then varied around 200 ft (60 m). The stopes worked as open stopes were partially filled after the recovery operation to within 6 ft (1.8 m) of the roof.

In 1971, the northern sector of the surface pillar was worked using the open pit method. A first bench, 40 ft (0.2 m) high was mined with no problem; however, from the beginning of the exploitation of a second bench, the central surface pillars caved-in into the unfilled areas of the underlying stopes. This cave-in happened about an hour after the dynamiting of the pit.

After this incident, no further activity was undertaken in the surface pillar area. The autorities simply stopped exploitation of the open pit mine, filled in the cave-in zone and left it to consolidate.

It was not until five years later that the decision was made to recover the rest of the pillars of the principal zone along with a second, subparallel vein, located 80 ft (24 m) further west.

The procedure was as follows:

1. Survey of the intact areas of the surface pillars;
2. Development of access under the pillars;
3. Cut-and-fill mining of zones I, II and IV (Figure 16.1) to 50 ft (15 m) from the rock surface;
4. Mining to the surface of zones I and IV using the "avoca" method (blasthole mining with immediate postfill);
5. Leaving a permanent surface pillar in zone II for safety.

In general, the ore lenses are worked longitudinally (1 300 ft, 400 m), across their full width (average 60 ft, 18 m). The height of the stopes is around 450 ft (137 m). The roof span is generally limited to 55 ft (17 m), but is occasionnally increased to 80 ft (24 m) where ground conditions allow it. The recovery percentage is close to 100 and the open stopes are filled about five or six months later.

The host rock poses no particular dilution problems with the cut-and-fill method, but locally, the low content massive sulfides need careful support.

Five operations characterize the working of the stopes:

- . Drilling
- . Blasting
- . Bolting
- . Loading
- . Filling

All cross sections of the stopes are performed with holes bored upwards. The diameter of the holes is 1 5/8 in (4.1 cm) and the drilling pattern is a mesh 4 ft x 6 ft (1.22 x 1.83 m). Holes are sloped at 65° towards the blasting and their depth is 14 ft (4.3 m) or 16 ft (4.9 m) according to the height of the cross sections to be exploited. The load factor of the holes is 0.45 lb/t (0.20 kg/t).

16.7 SUPPORT AND REINFORCEMENT METHODS

. Primary Support

No rib pillars have been left in the upper stopes.

. Filling and Reinforcement

Conventional bolts are used throughout the mine. Bolts with expansion shells and grouted or resin-anchored rebars are used in certain stopes of drifts. Near the caved-in area, cables and steel rebars are in use to maintain stability and to control dilution. The use of steel mesh is sometimes necessary in the flakiest zones. Wooden structures have been erected on top of the fill in a stope covering the northern part of the deposit. These measures were taken to increase the stability of the walls of a pillar made of low grade ore left in this stope.

The upper stopes have been only partially filled. The fill, crushed rock (50% weight) of 1 in (2.5 cm), is brought by dry road into the stopes.

Since 1977, the pre-bolting technique has been used to control stability in the roof of stopes where subhorizontally dipped joints have been observed.

Pre-bolting is done by drilling a hole 8 ft (2.4 m) long at every second drill line and inserting a structural steel rebar (#9) with resin. The first part of the hole is blasted in the normal fashion. This technique also reduces delays in the overall reinforcement work.

16.8 MONITORING PROGRAM(S)

. Stress Measurement

No stress measurements have been taken in the region of the surface pillars; some measurements, however, were made at the 2 800 level.

. Displacement Measurement

No displacement measurements have been taken in the region of the surface pillars.

. Other Programs

A summary visual inspection is carried out once every two weeks, but no report results from these visits.

16.9 SURFACE PILLAR DESIGN

. Personnel Involved

The departments involved in the design of the pillars are shown in Figure 16.4. The Engineering Planning Department initiates exploitation and sizes the pillars according to date received from the Rock Mechanics Department, Long Term Planning and Geology Departments. The Mine Superintendent and the Mine Engineering Superintendent approve or modify the planned dimensions. An outside consultant was hired for the following work: stress measurement, mathematical model, reinforcement and various technical consultations related to underground work.

. Chronology

As mentionned in section 16.6 (MINING OPERATIONS), exploitation of the surface pillars is staggered over several phases:

- open stope and sublevel mining of the stopes below 200 ft (15 m) deep;
- progressive cut and partial fill exploitation between 200 ft (60 m) and 50 ft (15 m) deep;
- partial exploitation of the deposit by open pit (one bench);
- partial exploitation of the deposit by the "avoca" method (blasthole and postfill) in the layer from 0 - 50 ft (15 m).

ORGANIZATION CHART - PILLARS DESIGN
ORGANIGRAMME - CONCEPTION DES PILIERS

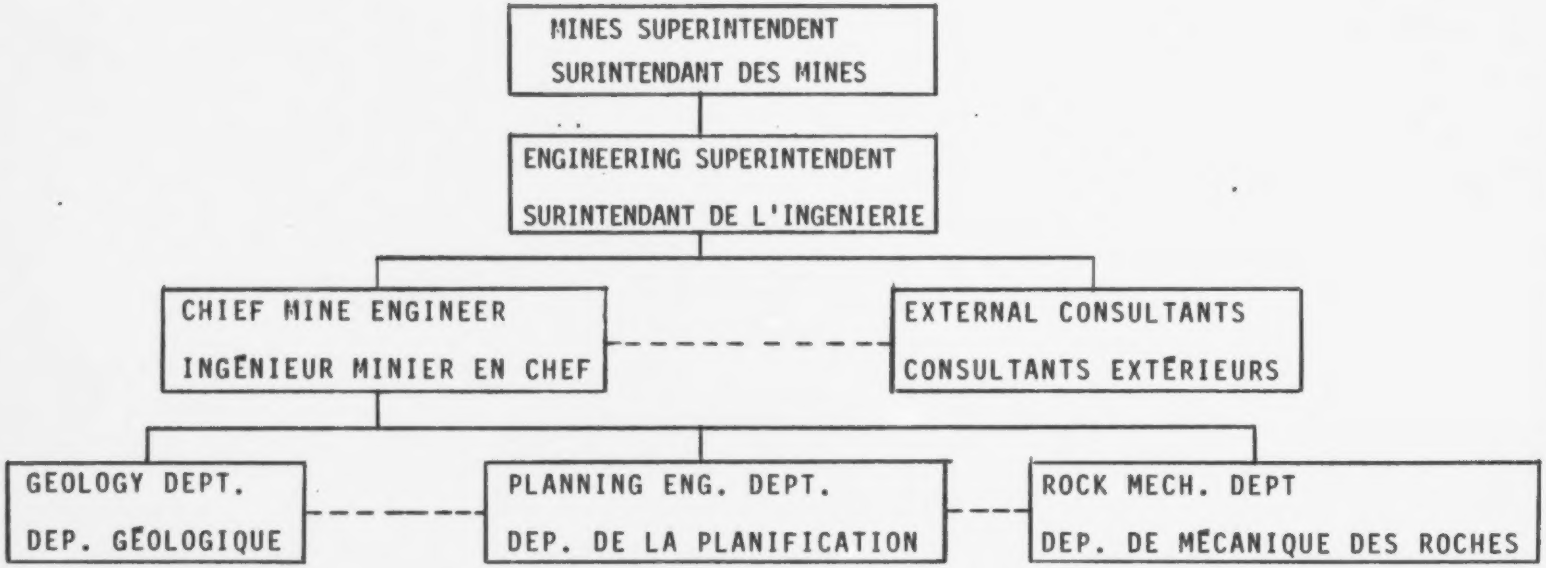
MINES SUPERINTENDENT
SURINTENDANT DES MINES
ENGINEERING SUPERINTENDENT
SURINTENDANT DE L'INGENIERIE
CHIEF MINE ENGINEER
INGÉNIEUR MINIER EN CHEF
EXTERNAL CONSULTANTS
CONSULTANTS EXTÉRIEURS
GEOLOGY DEPT.
DEP. GÉOLOGIQUE
PLANNING ENG. DEPT.
DEP. DE LA PLANIFICATION
ROCK MECH. DEPT
DEP. DE MÉCANIQUE DES ROCHES

FIGURE 16.4

Mine authorities mentioned that after the cave-in which took place right after the blasting of the second open pit, the underlying stopes situated between 200 and 495 ft (60 and 150 m) deep were systematically bolted and filled.

"Information gathered on a second mine already under exploitation by the Company"

About 6 mi (10 km) to the south-east of the mine visited, a second deposit was worked by the same Company. The exploitation began with an open pit to a depth of about 500 ft (152 m). The walls of the pit slope at about 65°. Later an underground ramp was dug from the bottom of the pit and two veins about 300 ft (91 m) apart were worked by the cut and fill method. The first of these veins was located in the wall of the pit while the others ran through the center. The upper part of the first vein was worked using the "avoca" method and the second was mined from 150 ft (46 m) to 50 ft (15 m) below the floor of the pit.

During exploitation of the pillar situated in the bottom of the pit, sound velocity in the rock mass surrounding the critical zone of the mining operation was determined on several occasions. Average readings of 300 to 400 in/s (800 to 1 000 cm/s) were recorded. Any sizeable decrease in sound velocity would have indicted a change in existing conditions of the rock mass. Visual inspections, monitoring programs based on surface stations (prisms) and on extensometers installed in the rock mass, and finally a model of the openings have been put into effect to follow ground conditions and to help prevent major incidents. Three prism stations were set into the walls of the pit and double theodolite readings were taken three times a day during the working of the last 50 ft (15 m) of ore in the bottom of the pit. This latter section was worked in two successive benches 25 ft (7.5 m) thick.

In conjunction with the readings from these stations, six extensometers distributed over the western wall were read daily. Two extensometers were inserted into a major fault crossing the pit in a WNW direction at an 80° NE dip.

The computer model predicted high concentrations of about 12 KSI (83 MPa) at the foot of the pit. The compressive strength of the rock was estimated at 6 - 7 KSI (40 - 50 MPa) and as predicted, the pillar fractured before the extraction of the last bench. Horizontal stress fields were estimated to be double the vertical stress fields.

. Design Factors

The initial setting of the surface pillar dimensions was based on the practical experience of the mine's personnel. The average thickness of these pillars was established as follows:

Thickness of the surface pillar = 3 x width of the underlying stopes

Later the mine directors decided to partially exploit the surface pillars following the aforementioned steps.

. Pillar Dimensions

Table 16.2 shows the present dimensions of the surface pillars and the underlying stopes: the ratio of the thickness of the pillar to the width of the stope ranges from 2.5 to 4.2.

DIMENSIONS OF SURFACE CROWN PILLARS

DIMENSIONS DES PILIERS DE SURFACE

TABLE 16.2
TABLEAU 16.2

DIMENSIONS		PILLARS - PILIERS							
		# 1	# 2	# 3					
. THICKNESS: EPAISSEUR:									
- WATER BODY PLANS D'EAU	feet-pi. (m)	-	-	-					
- OVERBURDEN MORTS-TERRAINS	feet-pi. (m)	*	(30) (9)	(30) (9)					
. SURFACE CROWN PILLAR: PILIER DE SURFACE:									
- THICKNESS EPAISSEUR	feet-pi. (m)	50** (15)	50 (15)	50 (15)					
- WIDTH LARGEUR	feet-pi. (m)	20 (6)	12 (4)	15 (5)					
- LENGTH LONGUEUR	feet-pi. (m)	220 (67)	160 (49)	105 (32)					
- THICKNESS/WIDTH RATIO RAPPORT EPAISSEUR/LARGEUR		2,5	4,2	3,3					
. STOPE HEIGHT HAUTEUR DU CHANTIER	feet-pi. (m)	450 (137)	450 (137)	450 (137)					
. FILL HEIGHT HAUTEUR DU REMBLAI	feet-pi. (m)	450 (137)	450 (137)	450 (137)					

* : Removed - enlevé
** : Exploited - exploité

16.10 VISUAL EVALUATION OF SURFACE PILLARS

The upper stopes are no longer accessible. However, information was gathered on the conditions of the rock mass by a visit of the open pit mine. Well developed, steeply dipping (60 - 70°) schistosity planes characterize part of the first bench worked. The rock mass in this bench also shows fracture systems producing blocks of dimensions varying from a few inches (cm) to several feet thick (6-10 ft: 2-3 m).

Near the open pit mine, the caved-in zone has been filled with waste rock and leveled on the surface.

No trace of water or of an hydraulic network has been observed at the surface.

An emanation of methane gas coming from the rock mass has been sighted in the first bench of the open pit mine.

16.11 MANAGEMENT'S COMMENTS

According to mine management, the cave-in of 1971 was the only major problem related ot the exploitation of the surface pillars. No characteristic or incident allowing the prediction of this cave-in was observed in the preceeding weeks. No one was injured in the cave-in as it happened shortly after the blasting of the second bench in the pit. The primary cause of this incident may be imputed to the high degree of fracturing of the rock mass and the effect of underground mining operations.

No problems with water have been encountered since the start of operations and current problems related to the mining operations and to the stability of the stopes do not concern the upper part of the deposit.

MINE #17

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17.0 SUMMARY OF THE VISIT

The deposit is composed of a regular vein of quartz-stibnite containing on average 13% antimony to a depth of five feet (1.5 m). The vein runs for 1 200 ft (366 m) and descends to a depth of more than 750 ft (230 m).

The only surface pillar is covered by an overburden varying between 0 and 6 ft deep. The piezometric level is situated lower than the soil-rock interface. Hydrogeological conditions in the rock mass are easily controled: 200 to 300 (US)GPM (12.5 to 19 L/s) are pumped from the mine.

The surface pillar, 70 ft (21 m) thick, covers a stope sloping at 33° randomly strewn with pillars. No fill is used and bolts are only installed locally at the deepest levels. The dimensions of the surface pillar are mainly dependent on the distribution of the ore in the upper part of the deposit.

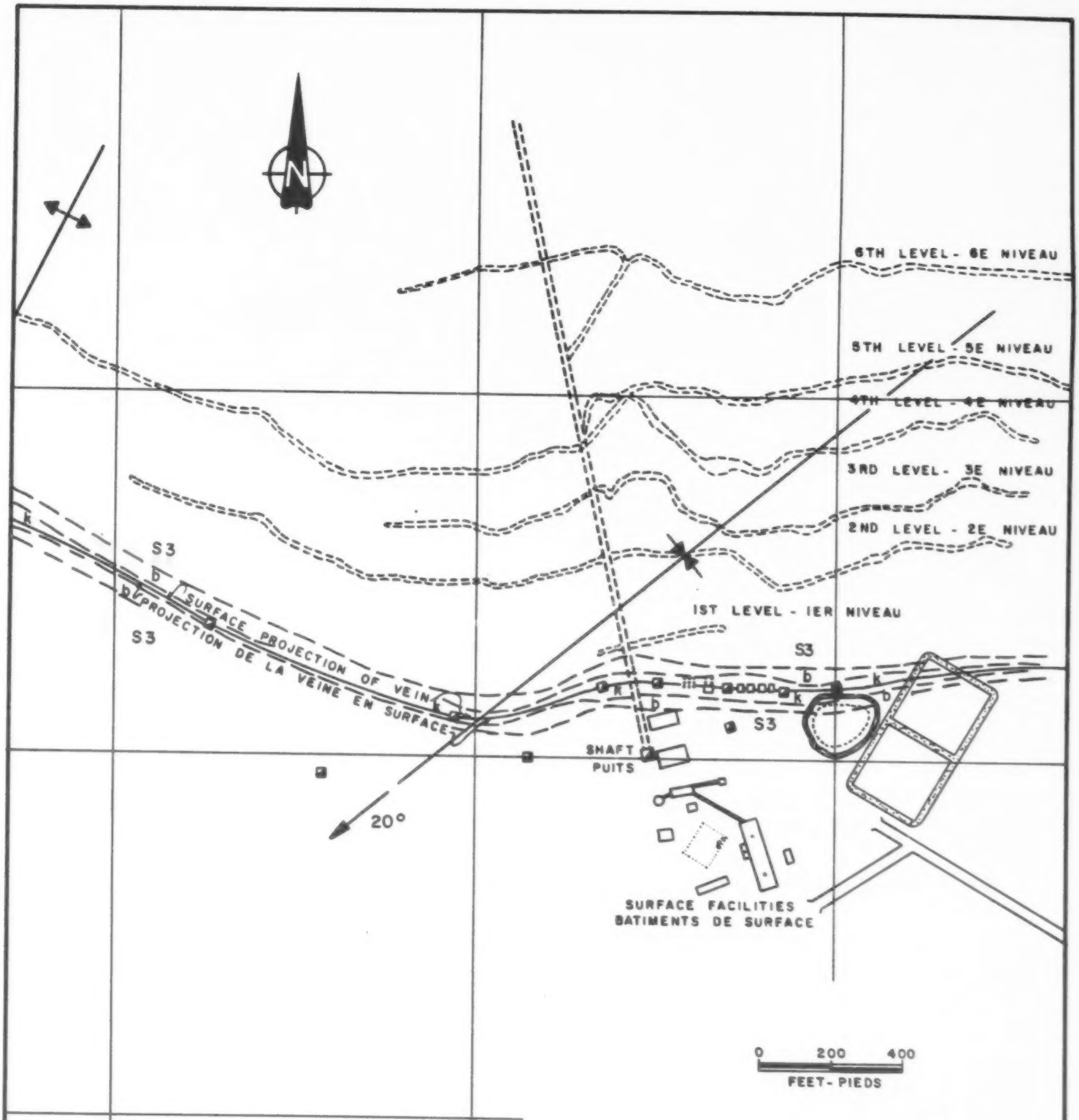
17.1 GENERAL INFORMATION

. Regional Geology

The mining property is located in the orogenic Appalachian Province , or more precisely in a band of graywacke of Silurian origin striking NE. To the north-west and the south-east of the graywacke are Devonian granitoid intrusions and sandstone and Pennsylvanian conglomerates respectively. The Acadian orogenisis produced a series of tight folds striking N-NE with a pronounced axial surface cleavage. The granitoid intrusions produced a metamorphic halo on contact with the ore zones. The green schist facies is typical of the region.

. Local Geology

The ore zone is made up of veins of quartz and stibnite crossing the graywacke at right angles (see Figure 17.1 and 17.2). An antiform and a synform created during the Acadian orogenisis are typical of this mining region; the axial surfaces of these folds strike N20°E and N50°E respectively. Lamprophyre dykes striking E-W and dipping at 80°S and porphyritic dykes of quartz and feldspar striking NNW and dipping at 80°SW intersect the host rock.


N
6TH LEVEL - 6E NIVEAU
5TH LEVEL - 5E NIVEAU
4TH LEVEL - 4E NIVEAU
3RD LEVEL - 3E NIVEAU
2ND LEVEL - 2E NIVEAU
1ST LEVEL - 1ER NIVEAU
S3
b
k
SURFACE PROJECTION OF VEIN
PROJECTION DE LA VEINE EN SURFACE
SHAFT
PUITS
20°
SURFACE FACILITIES
BATIMENTS DE SURFACE
0 200 400
FEET - PIEDS

LEGEND · LEGENDE

	Projected drift Galerie projetée
■	Ventilation raise Monterie de ventilation
b	Biotite Biotite
k	Sericite Séricite
S 3	Graywacke Grauwacke

ROCHE
associés ltée
Groupe-conseil

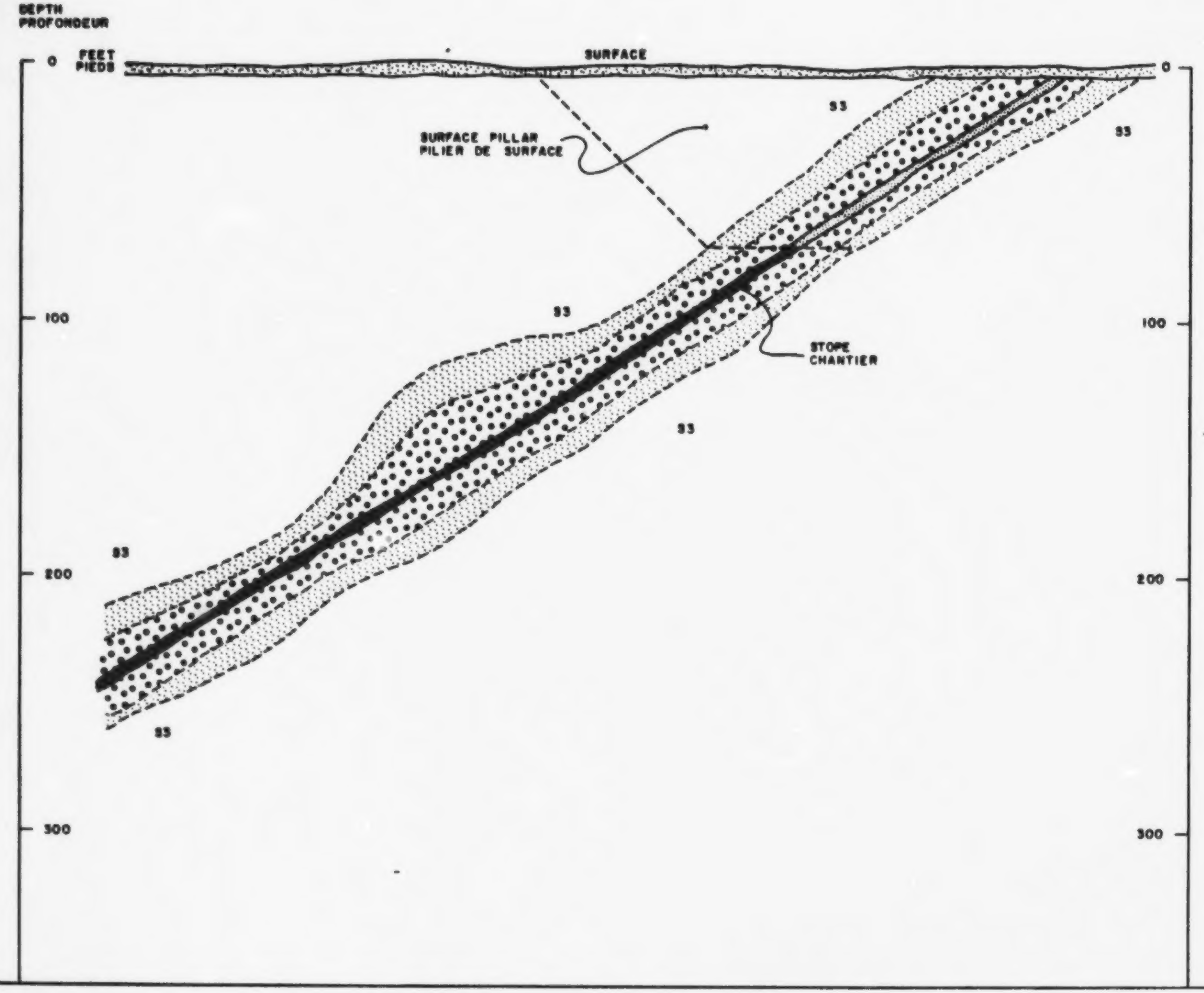
2535 boul. Laurier,
Sainte Foy, Quebec
G1V 4M3 Canada
(418) 871 9600
Telex QI: 051 31593

MINE # 17 MINE

SURFACE PLAN
PLAN DE SURFACE

Date 06/85

Figure 17.1


DEPTH
PROFONDEUR
FEET
PIEDS
0
100
200
300
SURFACE
SURFACE PILLAR
PILIER DE SURFACE
STOPE
CHANTIER
33
33
33
33
33
33
0
100
200
300

LEGEND - LEGENDE

■ Minerallized vein quartz - stibnite
Veine minéralisée quartz - stibnite

▨ Sericite zone
Zone de séricite

▨ Biotite zone
Zone de biotite

33 Country rock - greywacke
Formation régionale - greywacke

▨ Low grade mineralized vein
Veine minéralisée à basse teneur

0 20 40
FEET - PIEDS

TYPICAL SECTION
COUPE TYPE

ROCHE
associés ltée
Groupe conseil

2535, boul Laurier,
Sainte-Foy, Québec
G1V 4M3 Canada
(418) 871 9800
Télex (CB 051 31900

MINE # 17 MINE

GEOLOGICAL SECTION
COUPE GEOLOGIQUE

Date	Figure
06/85	17.2

17.2 MINE ENVIRONMENT

The surface buildings are situated about 200 ft (60 m) south of the surface pillar on the footwall side (see Figure 17.1). A sedimentation basin is located about 600 ft (180 m) south-east of the surface pillar. To the west, nearly 10 000 tons of reserve ore lies partly above the second level drift.

No measurement of surface settlement has been taken and no evident signs of instability have been observed in the area of the surface pillar.

A neighbouring abandonned mine is situated at about 500 ft (150 m) to the south-west of the western portion of the fourth level drift. This mine is currently flooded.

17.3 OVERBURDEN

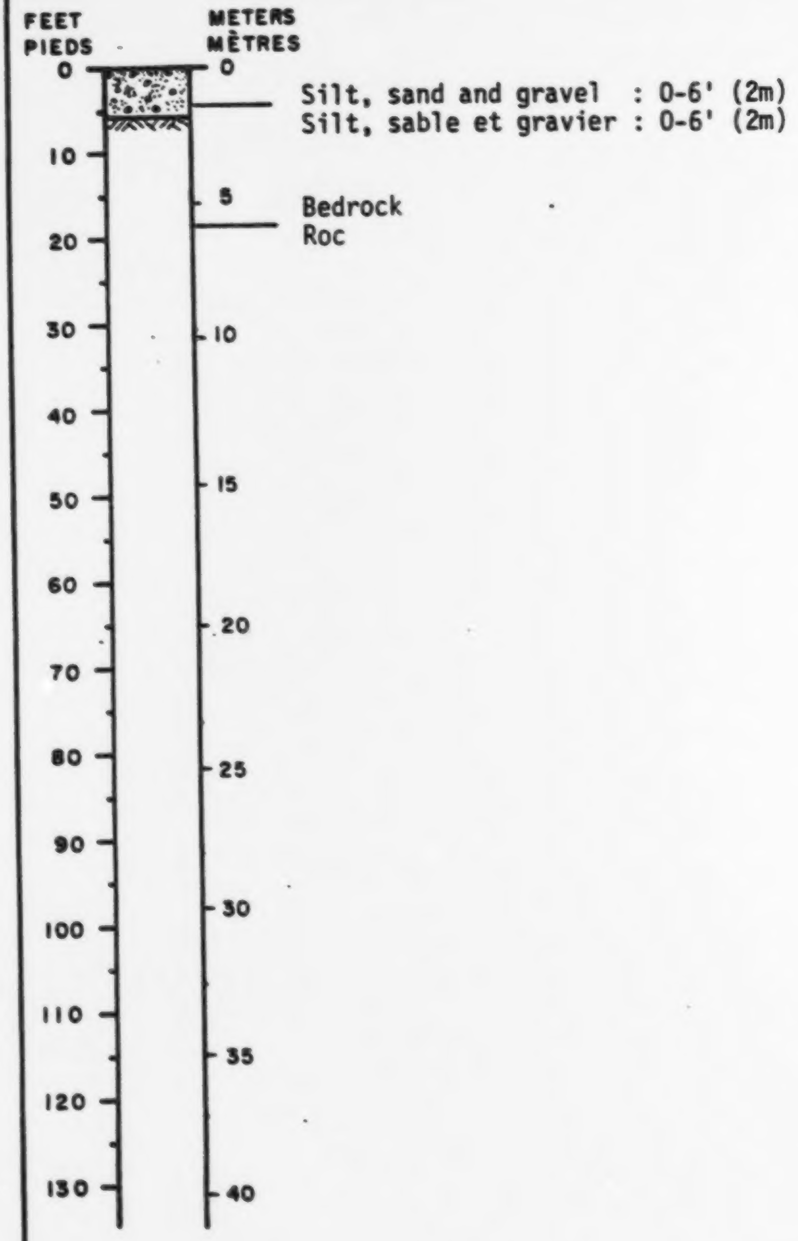
. Studies

No geotechnical study has been effectuated on this mining property.

. Stratigraphy and Characteristics

The thickness of the overburden above the surface pillar ranges from 0 to 6 ft (2 m). Soils are composed of silt, sand and gravel (see Figure 17.3).

SOIL STRATIGRAPHY
STRATIGRAPHIE DU SOL


FEET
PIEDS
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0
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70
80
90
100
110
120
130
0
5
10
15
20
25
30
35
40
Silt, sand and gravel : 0-6' (2m)
Silt, sable et gravier : 0-6' (2m)
Bedrock
Roc

ROCHE associée ltée Groupe-conseil 2535, boul Laurier, Sainte-Foy, Québec G1V 4M3 Canada (418) 871 9800 Télex : QBC 051 31593	MINE # 17 MINE	Date 07-1985	Figure 17.3

17.4 ROCK MASS

. Nature of the Rock

The rocks containing the ore are described as follows:

Footwall	: graywacke
Deposit	: vein of quartz and stibnite (antimony)
Hanging	: graywacke

Near the vein being worked, we find an alteration zone of about 400 ft (120 m) thick composed of a layer of silica (very thin), a zone of sericitization and a zone of biotite (see Figure 17.2).

. Structural Geology

The surface pillar is located on the south flank of a syncline striking N50°E and plunging at 20°SW (see Figure 17.1). The deposit lies on one of the east-west fracture planes that developed during the granitoid intrusions.

Joints are of varying lengths and are nearly closed. One family of joints has been identified:

Strike : 300 - 320°

Dip : sub-vertical

Joints are sometimes damp and contain fill material composed mainly of chlorite. According to management, R.Q.D. values may be qualified as good to very good.

. Characteristics

No geomechanical value has been determined for the host rock and the deposit. The density of the walls ranges from 2.4 to 2.8 and that of the deposit is evaluated at 4.6.

17.5 HYDROGEOLOGICAL CONDITIONS

. Overburden

The soils covering the surface pillar are above the piezometric level.

. Rock Mass

The dewatering of the mine poses no particular problem. About 200 (US)GPM (13 L/s) and up to 300 (US)GPM (19 L/s) are pumped to keep the mine dry. According to mine management, the rock mass has a low permeability coefficient.

17.6 MINING OPERATIONS

Mining Methods

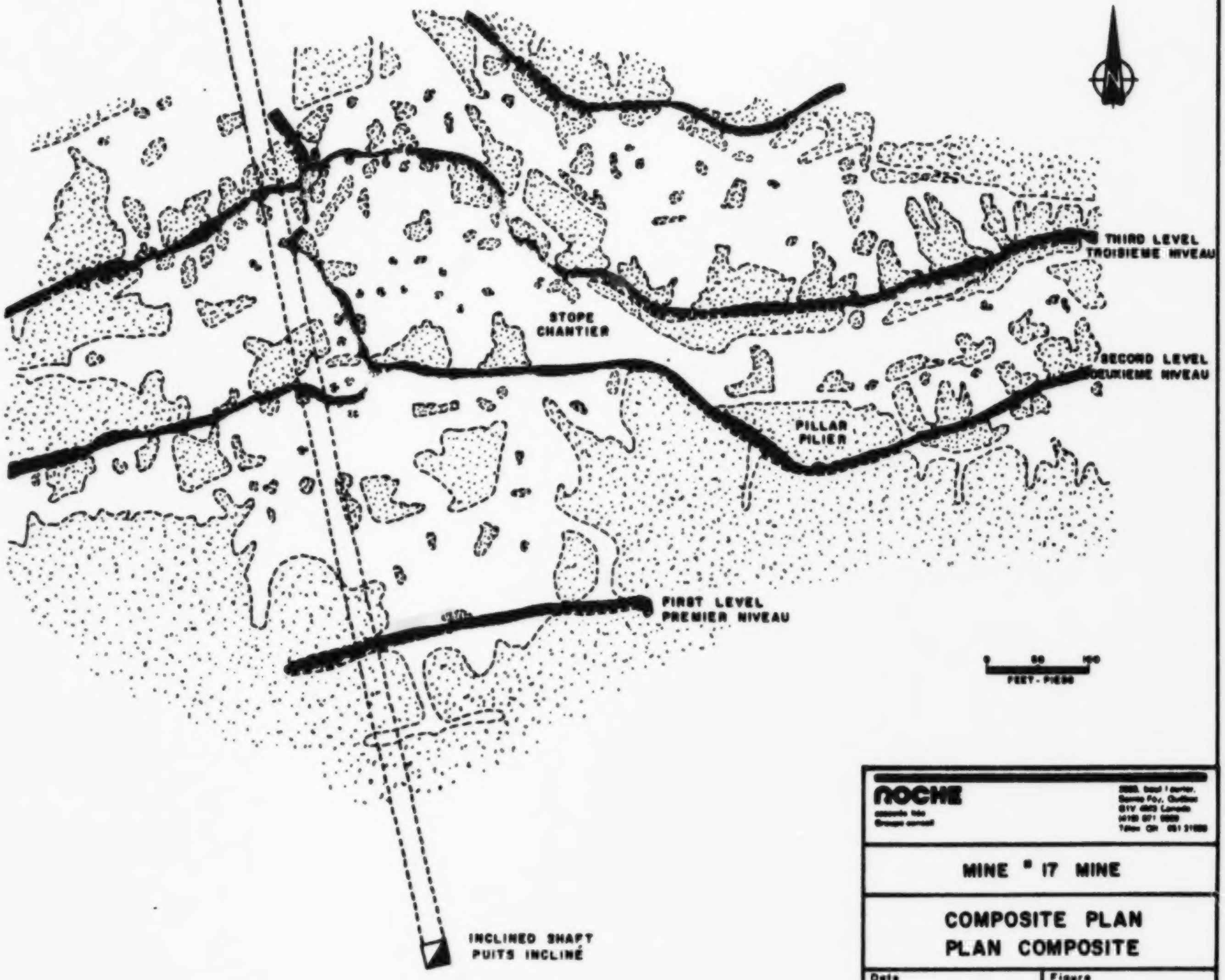
The deposit is mined by the stope-and-pillar method: pillars are spread eratically and are composed mostly of waste rock or low-content ore (see Figure 17.4).

Operating Conditions

Scrapers are used to bring the ore to the inclined shaft. Pillars situated below the second level are 30 ft (9 m) apart on the average and the levels are spaced at 100 to 150 ft (30 to 46 m).

The mining is carried out from the top to the bottom of the mine, leading away from the shaft at each level. In the upper part of the deposit, the extraction percentage was between 80 and 92% and dilution practically nil.

The drilling pattern used is 30 x 30 in (76 x 76 cm) with holes 8 ft (2.4 m) deep and 1¼ in (3.2 cm) in diameter.



N
THIRD LEVEL
TROISIEME NIVEAU
STOPE
CHANTIER
SECOND LEVEL
DEUXIEME NIVEAU
PILLAR
PILIER
FIRST LEVEL
PREMIER NIVEAU
0
50
100
FEET - PIEDS
INCLINED SHAFT
PUITS INCLINÉ

ROCHE

MINE # 17 MINE

COMPOSITE PLAN
PLAN COMPOSITE

Date	Figure
06/85	17.4

17.7 SUPPORT AND REINFORCEMENT

. Primary Support

The pillars, spread at random along the vein, form the primary support.

. Filling and Reinforcement

No filling is done in this mine. Conventional bolts 5 ft (1.5 m) long are used locally to prevent falling boulders. Resin-anchored bolts are also used occasionnally.

17.8 MONITORING PROGRAM(S)

. Stress Measurements

No stress measurements have been taken in this mine.

. Displacement Measurement

No displacement measurements have been taken in this mine.

. Other Programs

No particular control program has been developed as the mine's management feels that ground conditions are good and that the rock is competent. An annual visual inspection is the only control program used in the surface pillar.

17.9 SURFACE PILLAR DESIGN

. Personnel Involved

In practice, the mining of the deposit is limited to one stope which follows the slope of the ore vein. A geologist handles quality control and indicates the areas to be mined and the pillars to be left in place. The decision to increase the roof span or to use a certain bolting pattern is taken by the underground exploitation superintendent. The organization chart in Figure 17.5 shows the persons involved in pillar design.

No technical study has been done on the surface pillar.

. Chronology

Exploitation began at the top level and continued downward. No special procedure was followed during the exploitation of the upper portion of the deposit (i.e. the first level).

. Design Factors

The design factors used to establish dimensions are based on practical experience and on the distribution of the antimony content in the surface pillar. The latter was too low and exploitation work was stopped at about 70 ft (21 m) from the surface.

ORGANIZATION CHART - PILLARS DESIGN
ORGANIGRAMME - CONCEPTION DES PILIERS

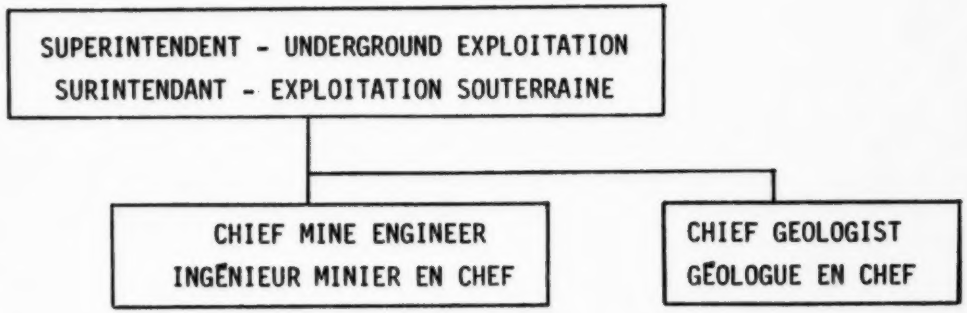

SUPERINTENDENT - UNDERGROUND EXPLOITATION
SURINTENDANT - EXPLOITATION SOUTERRAINE
CHIEF MINE ENGINEER
INGÉNIEUR MINIER EN CHEF
CHIEF GEOLOGIST
GÉOLOGUE EN CHEF

Figure 17.5

Management opted for a design procedure that applies to most of the pillars left across the vein:

Rock pressure : 1 psi/ft (22,6 kPa/m) vertical

Pillar compressibility : 10 000 psi (68.0 MPa) (including a safety factor of 3)

Considering that the average height of mining is 5 ft (1.5 m), minimum dimensions of the pillars should be twice the height, i.e. 10 x 10 ft (3 x 3 m) of the horizontal section.

Given the slope of 33°, the applied pressure should decrease by 1/3.

. Pillar Dimensions

The one surface pillar has a thickness/width ratio of 7. Table 17.1 shows the dimensions of the pillar and the height of the underlying stope.

DIMENSIONS OF SURFACE CROWN PILLARS

DIMENSIONS DES PILIERS DE SURFACE

TABLE 17.1
TABLEAU 17.1

DIMENSIONS		PILLARS - PILIERS							
		#1							
. THICKNESS: EPAISSEUR:									
- WATER BODY PLANS D'EAU	feet-pi. (m)	-							
- OVERBURDEN MORTS-TERRAINS	feet-pi. (m)	0-6 (0-2)							
. SURFACE CROWN PILLAR: PILIER DE SURFACE:									
- THICKNESS EPAISSEUR	feet-pi. (m)	70 (21)							
- WIDTH LARGEUR	feet-pi. (m)	10 (3)							
- LENGTH LONGUEUR	feet-pi. (m)	230 (70)							
- THICKNESS/WIDTH RATIO RAPPORT EPAISSEUR/LARGEUR		7							
. STOPE HEIGHT HAUTEUR DU CHANTIER	feet-pi. (m)	750 (229)							
. FILL HEIGHT HAUTEUR DU REMBLAI	feet-pi. (m)	0							

17.10 VISUAL EVALUATION OF THE SURFACE PILLAR

The hanging wall of the stope is marked by a fractured rock mass in which three joint systems are easily discernable. These three systems vary in strike and dip at three different places visited. The variable spacing of the joints produces parallepipedic blocks from a few inches (cm) to one foot (0.3 m) per side. The opening is normally small (0.03 in or 0.08 cm) and sometimes fill material made of quartz and chlorite is observed. Numerous veins and veinlets of quartz and chlorite cut across the rock mass and joint systems. The rock walls are dry and no flow of water was observed at the top level. The R.Q.D. is estimated at 30 - 50%.

The footwall shows similar characteristics to the hanging wall.

The interface of the deposit and the walls is distinct and the stope parallels the dip of the ore vein.

Some boulders from the roof or the walls were spread here and there on the floor of the first level.

The only method of reinforcement noted is the construction of wooden frames (12 x 12 ft or 3.6 x 3.6 m) intended to support the reputedly instable parts of the roof.

17.11 MANAGEMENT'S COMMENTS

Exploitation of the vein of antimony poses no particular problem at the moment and no fill is planned for the near future. The dimensions of the surface pillar were based on the decreasing distribution of ore towards the surface as far as the economical cutting grade.

Studies and efforts are more concentrated on the pillar surrounding the inclined shaft. Special attention is given to the distances to be maintained between the shaft and the stope which deepens progressively.

MINE #18

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18.0 SUMMARY OF THE VISIT

The mine is composed of massive sulfides lying in the west zone of the green rock belt, Superior Province. The deposit dips sharply at 55° to 80° to the east and strikes more or less to the north. The mine has been in operation since 1964, though the deposit was discovered in 1959.

The overburden above the deposit is about 80 m thick and composed mainly of lacustrian clay over fluvio-glacial sand and gravel.

The surface pillar of mine 18 has evolved considerably. Originally, the mine was worked as an open pit, then as an underground operation; afterwards the deposit located in the surface pillar was recovered. Since then, this area has been used for stock piling scrap from the mine. The dimensions of the surface pillar at the bottom of the open pit are 50 to 100 m wide, about 2 km long and about 30 m thick. Naturally, several pillars support this protective covering. The stopes are 18 m wide and the pillars 25 m; however, where heights of 80 m are attained, a crown pillar between the levels is about 23 m.

Several technical studies have been carried out at this site including hydrogeological, earth mechanics and rock mechanics studies. Various types of instruments have been used for measuring natural stress in the rock mass and deformations associated with both surface and underground operations.

The main rupture criterion used is the Mohr-Coulomb criterion. The evaluation of stress and pillar strength was based on empirical relationships built on the geometry of the pillar and on the load distribution at the tributary surface.

A sound knowledge of structural geology (at different levels) allowed accurate projection of mining problems and good structuring of the stability studies.

18.1 GENERAL INFORMATION

. Regional Geology

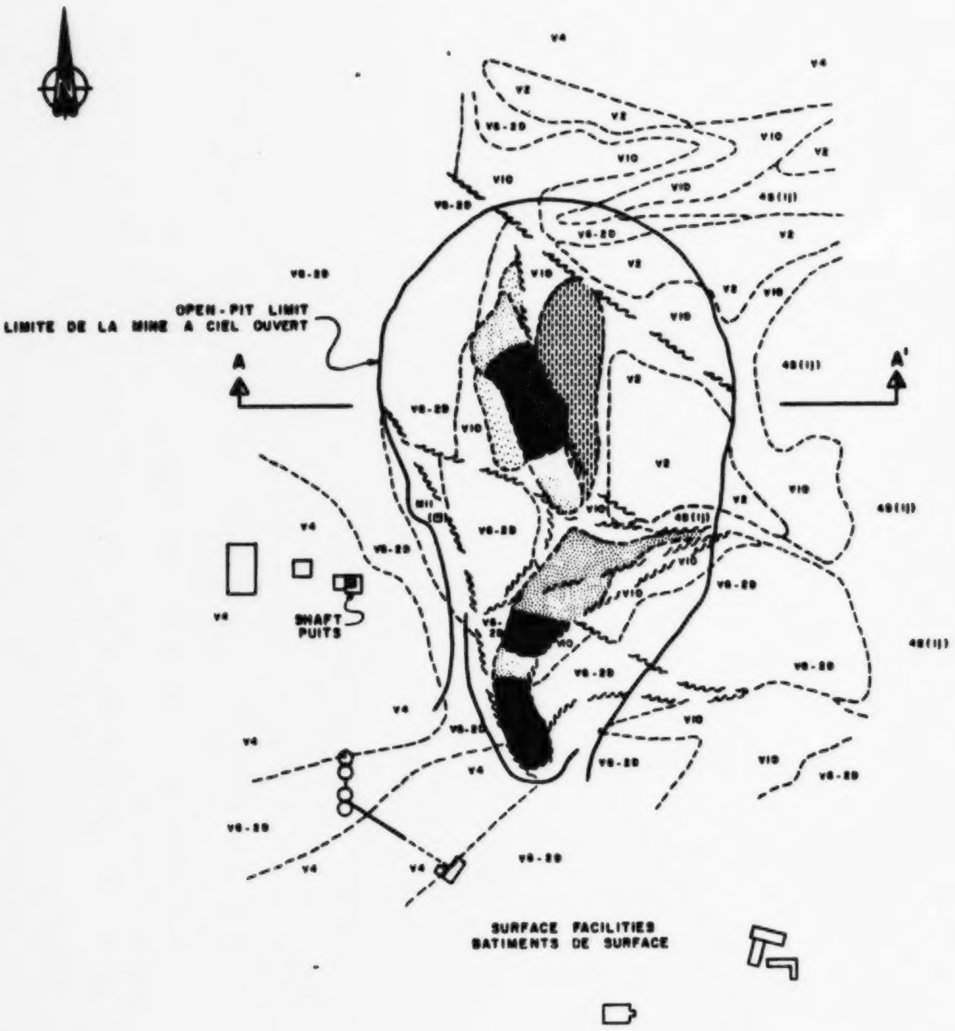
This mining property, #18, is located in a green rock belt. The rock in this area is well known as a privileged site for gold and base metal deposits from the Canadian Shield. In the area, the mainly acid and felsic volcanic rock dates from the Keewatin Period. This is covered by graywacke derived principally from volcanic rock. Sediment (mostly coarse clastic rock) from the Temiscamian is scattered about the rock.

. Local Geology

As indicated in Figure 18.1, the ore zone runs along a band striking more or less N-S and the deposit (Figure 18.2) slopes sharply. The deposit is located in a thickly piled zone of felsic volcanic rock composed mainly of volcaniclastic rhyolite covered by porphyric quartz, both naturally metamorphized. The ore is mainly contained in the upper portion of the rhyolitic rock in a carbonated horizon, a complex zone with a mixture of volcanic and sedimentary rock. The felsic stacking is covered by andesite (Figure 18.2).

. Characteristics of the Deposit

The mine contains a deposit of massive sulfide with surface dimensions of 168 x 670 m, and containing zinc, copper, silver, tin, lead and cadmium. It runs north with a dip to the east of 70-80° (Figure 18.2). The



OPEN-PIT LIMIT
LIMITE DE LA MINE A CIEL OUVERT
A
A'
SHAFT
PUITS
SURFACE FACILITIES
BATIMENTS DE SURFACE
V4
V2
V10
V6-20
4S(I)
MI1(2)

LEGEND - LEGENDE

▨	Massive, banded and breccia ore Minéralisation massive, laminée ou bréchiforme
▨	Carbonaceous, argillaceous horizon Horizon carbonaté et argileux
▨	Chalcopyrite stringer ore Minéralisation a veines et veinules de chalcopyrite
MI1(2)	Quartz porphyry Quartz porphyrique
V2	Massive rhyolite Rhyolite massive
V10	Rhyolite, volcaniclastics Agglomérats felsiques
V4	"Dacite" sequence Dacite
V6-20	Andesite - diorite Andésite - diorite
4S(I)	Predominantly altered ultrabasic Serpentinite à talc carbonaté
⁓	Faults Failles
■	Stopes Chantiers

0 250 500
FEET - PIEDS

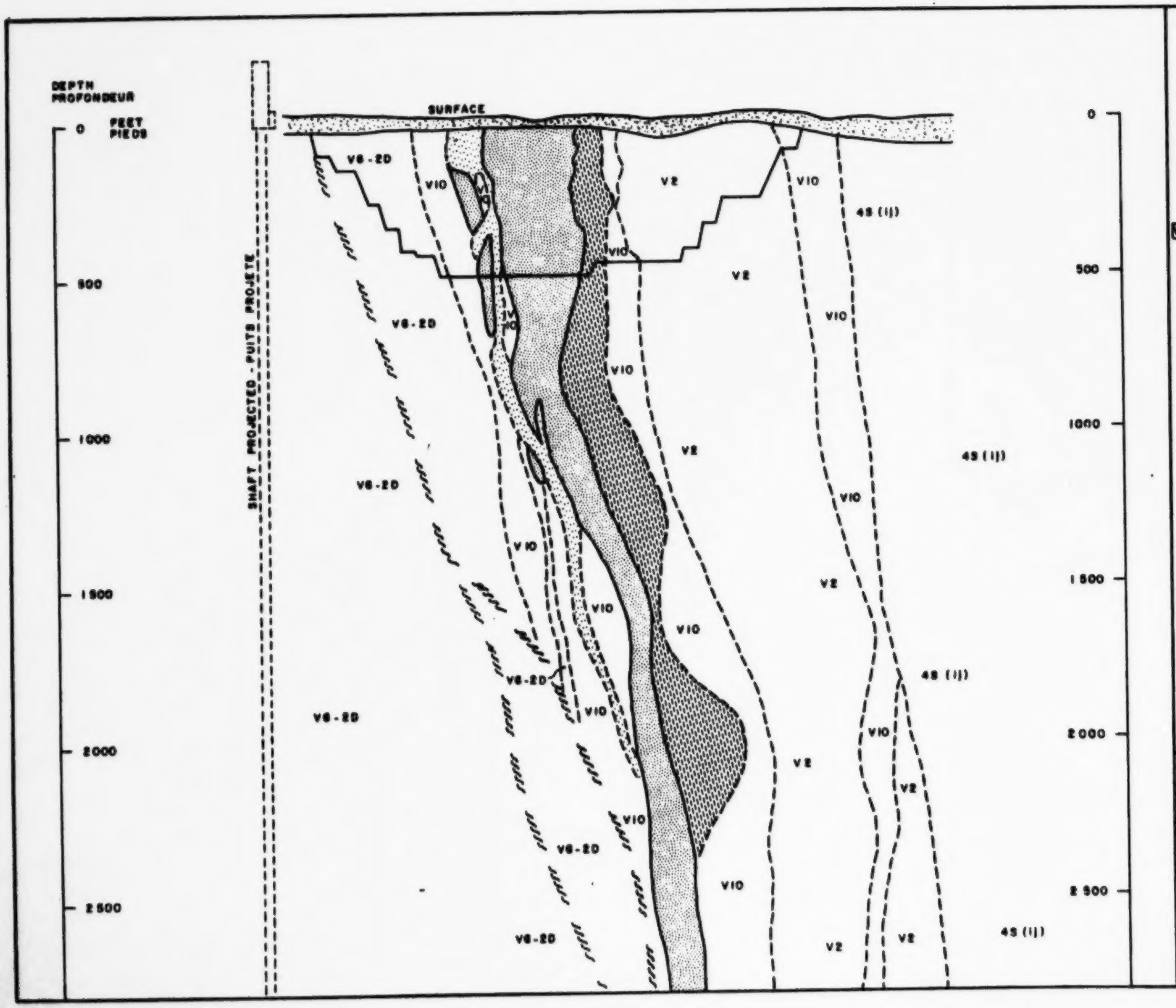
ROCHE
associés ltée
Groupe conseil

[illegible]
Sainte-Foy, Québec
[illegible] Canada
[illegible]
[illegible]

MINE # 18 MINE

SURFACE PLAN
PLAN DE SURFACE

Date	Figure
06/85	18.1


DEPTH
PROFONDEUR
FEET
PIEDS
0
500
1000
1500
2000
2500
SHAFT PROJECTED - PUITS PROJETE
SURFACE
V6-2D
V10
V2
4S (IJ)
LEGEND - LEGENDE
Massive, banded and breccia ore
Minéralisation massive, laminée ou bréchiforme
Carbonaceous, argillaceous horizon
Horizon carbonaté et argileux
Chalcopyrite stringer ore
Minéralisation à veines et veinules de chalcopyrite
V2 Massive rhyolite
Rhyolite massive
V6-2D Andesite - diorite
Andésite - diorite
V10 Rhyolite volcaniclastics
Agglomérats felsiques
4S(I) Predominantly altered ultrabasic
Serpentinite à talc carbonaté
Faults
Failles
Pit limit
Limite de la fosse
0
100
200
FEET - PIEDS

SECTION A-A'
COUPE

ROCHE
associés ltée
Groupe conseil

2535, boul Laurier,
Sainte-Foy, Québec
G1V 4M3 Canada
(418) 871 [illegible]
Télex [illegible]

MINE #18 MINE

GEOLOGICAL SECTION
COUPE GEOLOGIQUE

Date 06/85
Figure 18.2

deposit almost reaches the surface where it is covered by only a few meters (10 to 20 m) of overburden. It runs to a depth of at least 1 600 m.

The surface pillar at this mine is rather unique. Because of its geometry, the surface pillar was located at the bottom of the open pit mine previous to its recovery. Some of the Company's sketches seem to indicate that they considered the surface pillars as merely being that part of the deposit left between the bottom of the open pit mine and the upper area of the underground mine. The pillar ran the whole length of the open pit mine (about 2 km) and ranged in width between 50 and 100 m with a thickness of about 30 m. In one document, it was noticed that the surface pillar as defined by the Company, includes the lower part of the open pit mine.

18.2 MINE ENVIRONMENT

The mine was developed both at the surface and underground. As indicated in Figure 18.1's cross-section, the zone occupied by the open pit operation covers an area of more than 1 km^2. The open pit operation extended downward to about level 500 (150 m). Later, the Company exploited the underground mine in two distinct phases. About ten years ago, the Company decided to work the surface pillar from below. The present mine environment is such that the open pit mine is being used as a stocking area for waste and cuttings. The surface pillar has been recovered and all mining activities are now underground. The placement of the mine buildings is indicated in Figure 18.1; none is situated directly over the deposit.

18.3 OVERBURDEN

. Studies

Several years ago, the Company hired a firm of engineering consultants to evaluate the hydrogeological conditions around the open pit mine. More than thirty holes were drilled; most of them were limited to the loose deposit. In several cases the static level of the water in the holes was measured and the phreatic water table mapped. This allowed identification of the most permeable areas and determination of the thickness of the overburden above the mine. At about 100 m from the edge of the mine, the water level is 40 m deep while in the bottom of the open pit mine, it is about 140 m (in relation to the surface).

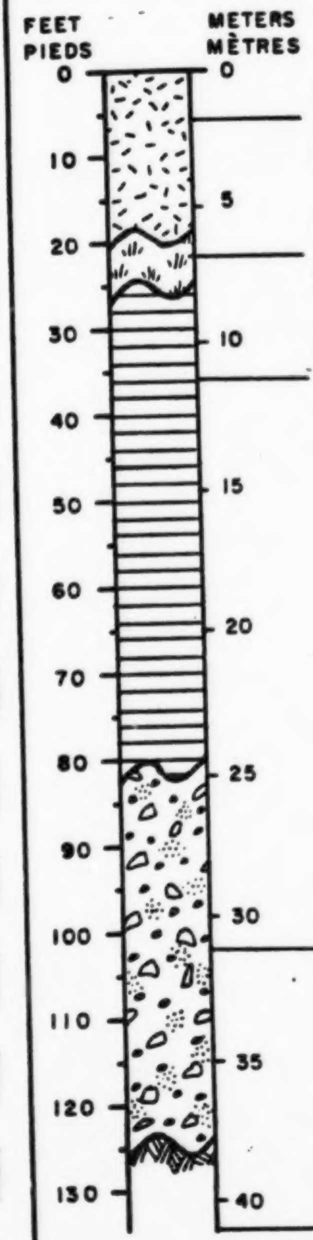
The drilling done during this study provided soil samples which were laboratory analyzed. The stratigraphic units above the mine are described in the following paragraph.

. Stratigraphy and Characteristics

Starting from the surface, the overburden above the mine is composed of 1 to 5 meters of fill material (unit 1), 1 to 2 meters of dark brown peat (unit 2), about 10 to 30 meters of stratified lacustrian soft to hard clay (unit #3), lying on 2 to 30 meters of sand, gravel and till (unit 4) (figure 18.3).

The results of the analyses and tests conducted on the different stratigraphic units are compiled in

SOIL STRATIGRAPHY
STRATIGRAPHIE DU SOL


FEET
PIEDS
METERS
MÈTRES
0
10
20
30
40
50
60
70
80
90
100
110
120
130
0
5
10
15
20
25
30
35
40

Fill	3 to 15 feet (1-5 m)
Remplissage	3 à 15 pi (1-5 m)
Organic soil	3 to 6 feet (1-2 m)
Sol organique	3 à 6 pi (1-2 m)
Clay	30 to 100 feet (10-30 m)
Argile	30 à 100 pi (10-30 m)
Sand and gravel	6 to 100 feet (2-30 m)
Sable et gravier	6 à 100 pi (2-30 m)
Bedrock	
Socle rocheux	

ROCHE
associés ltée
Groupe-conseil

2535, boul Laurier,
Sainte-Foy, Québec
G1V 4M3 Canada
(418) 871 9800
Télex: QBC 051 31583

MINE # 18 MINE	Date 07/85	Figure 18.3

Table 18.1. Some more specific tests on the stability of the slopes provided some data on the undrained shear strength of the clay. In the surface crust, about 3 m thick, the water content ranges from 12 to 24% and the density from 130-131 PCF($\approx$ 20 kN/m^3). The undrained shear strength reaches 3.5 KSF (168 kN/m^2) (measured with a scissometer.

TABLE 18.1
TABLEAU 18.1

SOILS CHARACTERISTICS
CARACTERISTIQUES DES SOLS

CHARACTERISTICS PROPRIETES	UNITES 1	2	3	4
Classification	-	-	CL	SW
Unit weight Poids unitaires	-	-	104-118 lbs/pi ^{3} (16-18 KN/m^3)	-
Wp (%)	-	-	17-26	-
Wl (%)	-	-	38-50	-
W (%)	-	-	34-64	-
Cu	-	-	0.2-1.1 KSF (10-53 KN/m^2)	-
C'(psi)	-	-	2 psi (14 KPa)	-
Ø	-	-	25°	-
St	-	-	3-6	-
SPT	-	-	-	35-75
K (cm/s)	-	-	10^{-8}	10^{-4}-10^{-5}

18.4 ROCK MASS

. Nature of the Rock

The ore zone contains three types of rock:

1. Laminated and brecciform massive sulfides (grey unit)
2. Carbonated and clayey horizons (situated in the lower part)
3. Veins and veinlets of chalcopyrite situated in the upper part of the ore zone.

This ore zone is interwoven with volcanoclastic rhyolite (unit V10). The hanging wall also has massive rhyolite (V2) and the footwall is composed of a complex of andesite-diorite (V6-2D).

In the foot and hanging walls, the visible alteration is of the chlorite and clino-torite type, while in the deposit there is evidence of recrystallization.

. Structural Geology

Fault and shearing zones slope sharply. In the area of the open pit mine, the part shearing zones slope 70-80° to the east. Part of the hanging wall may dip as little as 55°. In the andesite-rhyolite zone of the hanging wall, a survey of the discontinuities indicates three families of joints with the following dips:

Direction and dip joints:

1. 291°/41°
2. 142°/90°
3. 352°/84°

Table 18.2 summarizes the structural characteristics of the walls and the deposit. The tectonic forces acting on the rock mass are compiled in Table 18.3, and indicate that the axis of the major stress is approximately E-W. Deeper in the mine, variation in the magnitude is slight whereas the strike changes greatly.

. Characteristics

The compiled results of rock mechanics tests are presented in Table 18.4. Compressive strength values are given only for tests done on samples of 4.1 cm in diameter; at a larger diameter, the values are naturally lower and more representative. Most of the units appear very competent except for the rhyolites which shows a rather low R.Q.D. value.

TABLE 18.2 STRUCTURAL DATA - JOINTS
TABLEAU 18.2 DONNEES STRUCTURALES - JOINTS

Characteristics Caractéristiques	Foot wall Eponte inférieure	Orebody Gisement	Hanging wall Eponte supérieure
Spacing in. Espacement (cm)	3 - 36 (8 - 91)	3 - 36 (8 - 91)	10 25
Aperture Ouverture	Tight Serré	tight Serré	tight Serré
Continuity Continuité	Continuous Continu	Continuous Continu	At random Aléatoire
Joint set number Nombre de familles de joints	2(3)	2(3)	-
Infilling Remplissage	Quartz-limestone Quartz-carbonate	Quartz-limestone Quartz-limestone	Quartz Quartz

TABLE 18.3 "In situ" stress

TABLEAU 18.3 Contraintes "in situ"

	σ_1		σ_2		σ_3	
Depth Profondeur pi (m)	KSI(MPa)	strike/dip dir./pen.	KSI(MPa)	strike/dip dir./pen.	KSI(MPa)	Strike/dip dir./pen.
1600 (488)	4.8(33)	094/06	3.9 (27)	186/23	1.6 (11)	350/60
2400 (732)	10.6(73)	258/19	9.4 (65)	358/25	4.9 (34)	135/58
2800 (853)	7.7 (53)	250/10	7.5 (52)	342/09	2.7 (19)	112/27
2800 (853)	7.7 (53)	077/12	5.8 (40)	170/18	2.3 (16)	318/70

TABLE 18.4
TABLEAU 18.4

GEOMECHANICAL CHARACTERISTICS CARACTÉRISTIQUES GÉOMÉCANIQUES					
Rock type Type de roche	Density Densité	RQD RQD %	Qu Qu (KSI) (MPa)	E E (GPa)	u u
Andésite/ diorite	2.96	82	29 (202)	12 (81)	0.23 0.14
Serquanite	2.70	72	21 (147)	12 (81)	0.14
Andésite/ diorite Shear zone Zone de cisaillement	2.85	-	17 (117)	12 (81)	-
Orebody Gisement	3.33	83	23 (159)	11 (73)	0.21
Rhyolite	2.75	50	8 (53)	7 (50)	-
Rhyolite/ tuff	2.70	-	24 (127)	11 (74)	

18.5 HYDROGEOLOGICAL CONDITIONS

A hydrogeological study was conducted towards the end of the 1970's. Moreover, several piezometers were installed during the geotechnical work carried out to study the stability of the slopes of the open pit mine.

. Overburden

In the overburden, the water level is very low, that is at about 20 m deep. The stratigraphy revealed the presence of relatively impermeable layers (with permeabilities of about 10^8 cm/s). Water generally enters the mine at a rate of 1 500 liters per minute, but several million liters can enter the mine during the spring thaw or during heavy rains.

. Rock Mass

In 1973, a geotechnical study indicated that most of the open pit mine was dry. The water level in a shaft situated in the bottom of the excavation (in the deposit) reached about 13 m below the level of the collar. In this shaft, an on-site permeability test (variable head test) gave a value of 9.8 and 3.5 x 10^6 cm/s. Such results are typical of compact and relatively impermeable rock. No other values are available for different lithologies.

18.6 MINING OPERATIONS

. Mining Methods

The initial mining operations were intended to extract the ore from the open pit mine during development of the underground stopes. The underground mine is developed by levels staggered every 122 m beginning at level 244 m (level 800) with sub-levels 30.5 m apart. The open stope blasting technique is used. This results in 18 m stopes leaving a crown pillar of 26 m between the exploitation levels. Management intend to fill the stopes with cemented waste before mining the pillars.

. Operating Conditions

For the blasting of the stopes, drill holes 20 cm in diameter and 40 m long were used. The powder factor is estimated at 6 kg/t. Recovery in the stope always begins by drilling an access 1.8 m in diameter at the principal level as far as the highest sub-level. An opening 3 m wide is then dug using the 20 cm holes spaced every 2.4 m with a covering of 2.1 m, giving a total of 16 holes. The main annulus of the drillings of these holes are spaced every 5.1 m with a recovery of 4.5 m. Near the former recovery areas, the drilling pattern is tighter to minimize damage to the walls. Dilution is estimated at 10% and 100% recuperation of the ore is expected.

18.7 SUPPORT AND REINFORCEMENT METHODS

. Primary Support

Primary support is provided by the pillars whose dimensions have been mentioned previously.

. Filling and Reinforcement

A soon as the ore is extracted, the stopes are filled with waste rock. The fill is composed of 20% rock and sand and 80% crushed waste mixed with cement of not more than 15 cm. Sand is added in some cases to increase the quantity of fines.

Reinforcement is used as needed and consists of anchor bolts 1.5 m long spaced every 1.2 m.

18.8 MONITORING PROGRAM(S)

. Stress Measurement

"In situ" stress measurements were conducted using three (3) CSIR doorstoppers at the 488 m, 731 m and 835 m levels. The results are reproduced in Table 18.3. Stress redistribution was thereafter evaluated using extensometers.

. Displacement Measurement

In the open pit mine, several geodesic targets were installed before the blasting of the surface pillar in the bottom of the pit so that evolution of the deformations could be followed. In all, 56 targets were installed between 1973 and 1976; they were all read by a 700 and 710 geodimeter about once a month.

In the underground mine, there are six (6) extensometers installed at level 800 to evaluate stress redistribution when blasting stopes and pillars.

18.9 SURFACE PILLAR DESIGN

. Personnel Involved

The Mine Engineer, the Geologists and Geotechnicians, especially Rock Mechanics personnel were involved in designing the mine, and more specifically the open pit mine and the underlying surface pillar.

For some specific aspects, the Company used the services of outside (hydrogeology and soil mechanics) consulting firms or collaborated with CANMET in certain research studies.

. Chronology

The exploitation of the upper part of the deposit followed these steps.

- Open pit mining
- Underground mining at level 800 and below
- Mining of the surface pillar

In all the cases under study here, the initial surface pillar has been completely recovered. In this case, a surface pillar always remains after exploitation, but it no longer contains a deposit; moreover, its geomechanical characteristics have been greatly changed given that the exploitation zone has been filled. The critical part of the design process was the prediction of the behaviour of the rock mass during blasting of the surface pillar.

Because of this, several ground studies were conducted and were coupled with simulations using programs 2D and 3D as finished elements. The different geomechanical situations of the surface pillar can then be evaluated (Figure 18.4):

- Transfer of the stresses to the surface pillar during excavation of the open pit mine
- Transfer of the stresses in the lateral pillars during excavation of the stopes
- Transfer of stresses to adjacent lateral pillars during sequential blasting of the pillars and evaluation of the support provided by the stopes filled with cemented waste.

. Design Factors

For these calculations, they used Mohr-Coulomb's rupture criterion with an average friction angle of 28.8, cohesion varying from 0.39 to 1.84 MPa and an average density of 2.9 kN/m^3.

For the sizing of the pillars, horizontal stress was measured at several levels and the following equation used:

$$\sigma H = 8.00 + 0.041\ H$$

where H is the height in meters. The applied stress was evaluated using the stress distribution by the tributary surface method.

Thus the stress supported in the central pillars was:

$$\sigma P = \sigma H/(1-R)$$

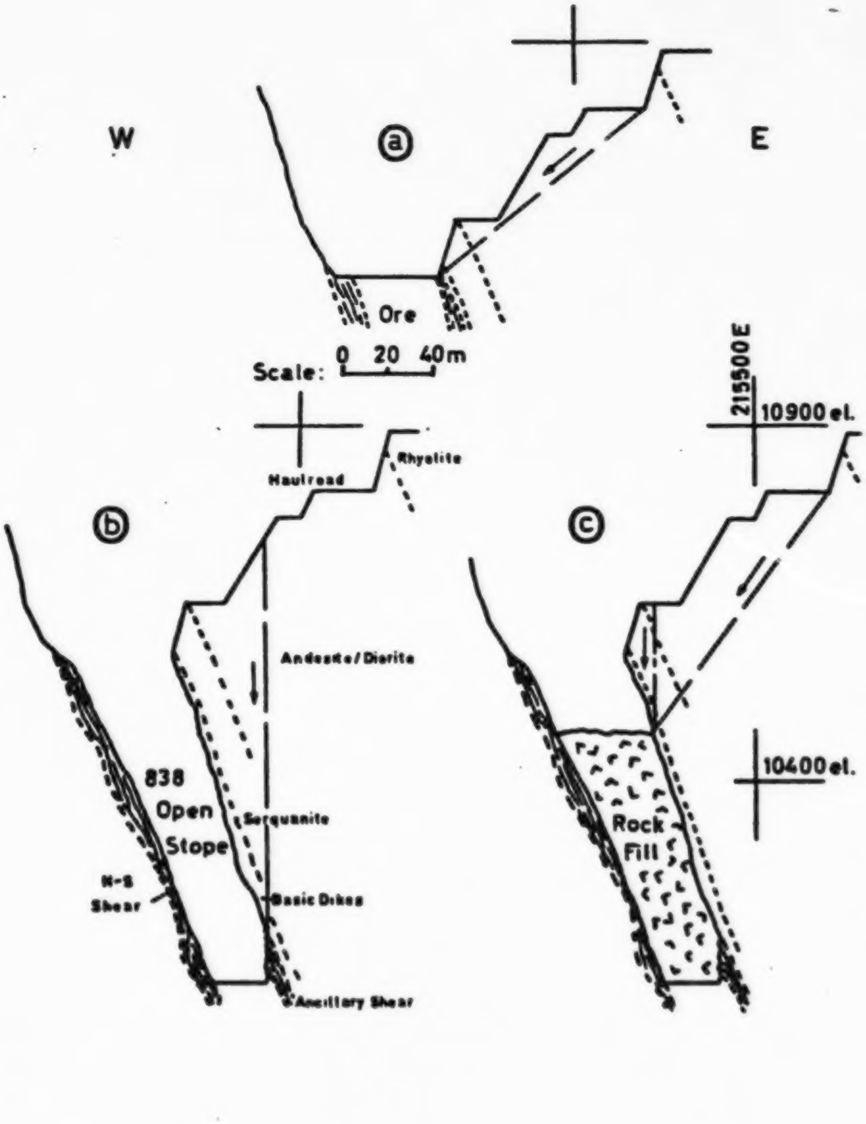

W
ⓐ
E
Ore
Scale: 0 20 40m
215500E
10900 el.
Haulroad
Rhyolite
ⓑ
ⓒ
Andesite/Diorite
838
Open
Stope
Serquanite
N-S
Shear
Basic Dikes
Ancillary Shear
10400 el.
Rock
Fill

Figure 18.4 Potential failure plans
Plans de rupture potentiels

where σP is the average stress acting on the pillar (in MPa) and R is the extraction rate.

Pillar strength was evaluated using the following empirical equation:

$$Qu = {}_{f}K\ X^{a}/H^{b}$$

where Qu is pillar strength (in MPa), W is the width of the pillar in meters, H the height of the pillar (in m) and K the strength of 0.305 cubic meters of rock. A and b are constants. The equation results for mine #18 are as follows:

If $b = 0.65$ $\quad Qu = 0.837\ K\ W^{0.5}/H^{0.65}$

If $b = 0.75$ $\quad Qu = 0.743\ K\ W^{0.5}/H^{0.65}$

. Pillar Dimensions

Before their exploitation, the surface pillars had the following dimensions, based on the size of the underlying stopes:

width: 18 m
thickness: 30 m
length: variable
thickness/width ration: 1.7

18.10 VISUAL EVALUATION OF SURFACE PILLAR(S)

Does not apply in this case.

18.11 MANAGEMENT'S COMMENTS

Company management feels it is very important to well integrate knowledge on geology and geomechanical properties of the rock masses. Management insisted on the importance of good understanding of the structural geology of the deposit and the walls in order to accurately predict the reaction of the mass when exploitation is begun and especially how the tectonic history (folds, faults) influence mining operations.